INSIDE NATURE'S LIGHT SHOWS

SPECIAL 100th ISSUE CELEBRATION

HOW IT WORKS

FEED YOUR MIND WITH...

100 WONDERS

CELEBRATING THE INCREDIBLE WORLD AROUND YOU

★★★ INCLUDING... ★★★

- HOW FLIGHT CHANGED THE WORLD
- ONBOARD THE SPACE STATION
- HOW THE INTERNET WORKS
- THE AMAZON RAINFOREST
- BUILDING STONEHENGE

+ THE HUMAN BRAIN

VR TECH
IS IT REALLY THE FUTURE?

10 MARVELS OF THE ANCIENT WORLD

Future
ISSUE 100
Digital Edition
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BUMPER READERS SECTION **LOOKING BACK: 100 COVERS** THE WORLD IN 2025
SPECIAL QUIZ GIVEAWAY BEHIND THE SCENES: HOW *HOW IT WORKS* WORKS

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ISSUE 100

WELCOME

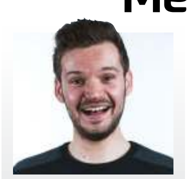
The magazine that feeds minds!

"Each section of the International Space Station was launched separately and assembled in orbit"

Out-of-this-world facts about the ISS, page 80

Meet the team…

Charlie
Production Editor
Humanity's ability to create incredible things is widely appreciated, but what about the wonders of the natural world around us? Head over to page 54 for some of Mother Nature's finest work.



Jack
Senior Staff Writer
For me, the greatest wonder this issue is the revolutionary printing press – we wouldn't have this magazine without it. It's time for me to say farewell as this is my last issue. Bye!

James
Research Editor
With 100 wonders to choose from, we're all spoiled for choice when it comes to picking our favourite. For me, the most amazing of them all comes last on our list, which you can find on page 88.

Duncan
Senior Art Editor
I still can't believe it's issue 100 already! I was there at the start, helping to launch this amazing magazine all the way back in 2009! Even after all this time, it still manages to feed my mind.

Laurie
Studio Designer
My favourite wonder in this issue has to be number 66 – pufferfish crop circles. It blows my mind how a fish so tiny can make such a detailed masterpiece in an attempt to impress a passing mate.

FOLLOW US… How It Works magazine @HowItWorksmag

Welcome to our 100th issue! This month, the magazine is filled with as many amazing sights, creations and phenomena as we could pack into its pages. Reducing the list to just 100 wonders was tough, but we hope you agree with what has made the cut.

We wouldn't have reached this milestone without our readers, so thank you for picking up a copy or subscribing! The team love to hear what you think, so do keep sending us your questions for us to answer and comments for what you'd like to see in future editions of **How It Works**.

It's difficult to pick a favourite wonder, but the International Space Station is definitely one of mine. Knowing that it was put together while orbiting the Earth at thousands of kilometres per hour never fails to amaze me. But to me, its most important feature is how it has become a symbol of international cooperation and a model of what can be achieved when humanity works together.

We hope you enjoy the issue!

Jackie **Jackie Snowden**
Editor


HOW IT WORKS
THE MAGAZINE THAT FEEDS MINDS
TYPHOON VS F-22 RAPTOR
CAN WE LIVE ON MARS?
BRAIN POWER
PREHISTORIC PREDATORS
THE SCIENCE OF SPEED
SOLAR SYSTEM
INSIDE THE iPAD
DIETS
TOUCH SCREEN TABLETS
ROCKET SCIENCE
INTERNET TV
MUSCLE POWER
THE GALAXY
GREATEST MYTHS
DEADLY VENOM
SURVIVING EXTINCTION
SEARCH FOR NEW EARTH
ATOMS
ENGINEERING WONDERS OF THE WORLD
SUPERSMART TVS
THE NEW CONCORDE
HYPERCARS
INCREDIBLE EARTH
SPACE PLANES
GENETICS
GREATEST INVENTIONS
ENERGY EXPLAINED
THE HUMAN BODY
COMBAT VEHICLES
3D PRINTING
JETPACKS
RACING CARS
SKY GIANTS
SURVIVING EXTREME EARTH
OCEAN HUNTERS
APPLE WATCH
FIGHTER PLANES
101 GIGANTIC FACTS ABOUT DINOSAURS
SUPER SOLDIERS
AEROBATIC DISPLAYS
THE WORLD'S DEADLIEST PREDATORS
MAGNETISM
WHAT IF... DINOSAURS DIDN'T DIE OUT?
SUPER SUBMARINES
BECOME A TOP GUN
SUPER DRONES
ELECTRIC VEHICLES
ATTACK HELICOPTERS
BIG CAT ATTACK
HYPERSONIC FLIGHT

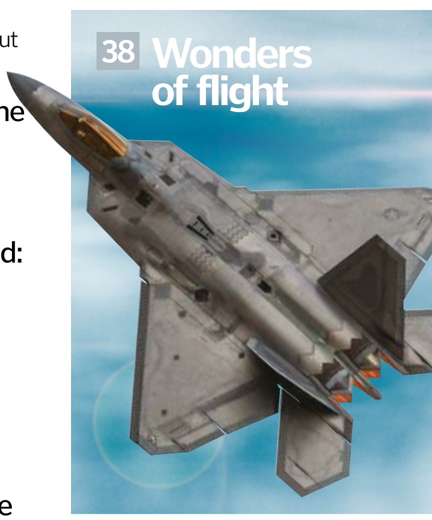
THE 100 COVERS

From fighter jets to robots, and dinosaurs to Mars colonies, we've covered a lot in our first 100 issues, with so much more to come...

CONTENTS

SPECIAL 100th ISSUE CELEBRATION

+ THREE PULL-OUT POSTERS!
PAGES 48-53



MEET THE ISSUE 100 EXPERTS...

Joanna Stass
This month, Jo takes us on a historical tour of some of the world's most incredible structures. She also explains the tech behind cameras and Microsoft's Hololens.

Laura Mears
Biology expert Laura explains the wonders of the human brain in our science feature. She also tells us why water's weird chemical properties make it vital for life.

Ella Carter
From the Coral Triangle to Madagascar, and the Amazon to the Galápagos, Ella highlights some of the world's most incredible habitats in this month's environment feature.

Jonny O'Callaghan
In our space feature, Jonny gives us eight reasons why the International Space Station inspires awe. He also explains how reuseable rockets will change spaceflight by improving costs and efficiency.

Stephen Ashby
Steve brings you this issue's How To experiments. Find out how to make a tornado in a jar, and how fruit juice can make your old tarnished coins look shiny and new!

MEGA GIVEAWAY

WIN £2,500 OF GADGETS, TOYS, TICKETS AND BOOKS

PAGE 10

REGULARS

SPECIALS

SUBSCRIBE NOW!

Go to page 94 for great deals

Mike Bedford
From the jet engine to commercial airliners and supersonic planes, Mike explains how the wonder of flight has changed the world in this month's transport feature.

Katy Sheen
How It Works alumnus Katy returns to explain how stem cells could revolutionise medicine, and points out where you can spot mathematical phenomena hiding in nature.

Steve Wright
This month, Steve explains why cargo ships are vital for modern life as we know it. He also finds out what the future holds for electric cars, and how bullet trains break records.

Mike Simpson
In our technology feature, Mike explains the inner workings of all the gadgets and utilities we take for granted, from smartphones to drinking water.

Sarah Bankes
Sarah explains some amazing natural phenomena in this issue, from mysterious whale song, pufferfish 'crop circles', diamond formation and why snowflakes are unique.

HAVE YOUR SAY

How It Works would not have reached issue 100 without you, our readers!

SPECIAL 100th ISSUE CELEBRATION

Letter of the Month

Fuel cells and gamma rays

Dear **HIW**,
The magazines have been constantly engaging, saturated with fun facts and in-depth articles. How It Works is an incredible magazine and I am looking forward to many further issues. I found the cover photo of issues 64 and 78 particularly eye-catching.
I have a few questions: are hydrogen fuel cells as efficient yet as lithium-ion batteries for cars? If so, why aren't hydrogen cars as common as electric cars? Also, how exactly do gamma rays kill living cells?
Thank you,
Anish Mariathasan

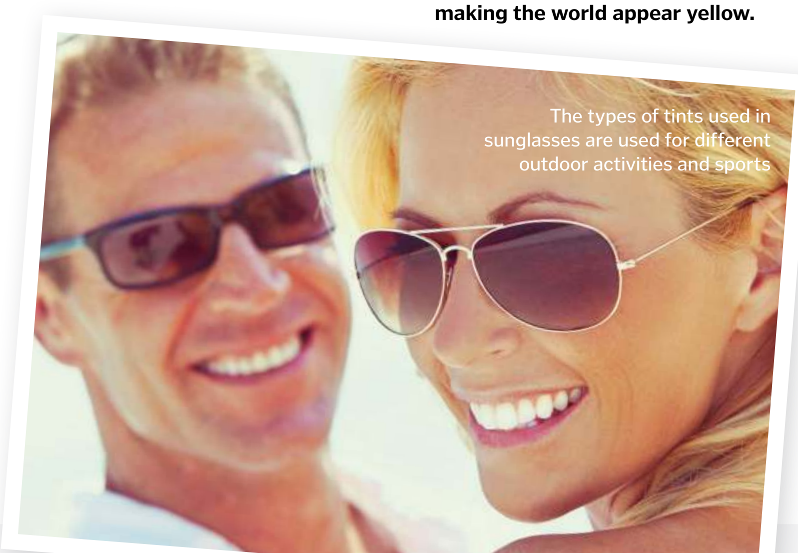
We're glad you enjoy the magazine Anish! To answer your first question, hydrogen fuel cell vehicles are still less efficient than all-electric battery vehicles in terms of distance travelled per unit of energy consumed. One of the downsides of hydrogen is that, even though it is the most abundant element in the universe, most of it does not naturally exist in its pure form on Earth. Hydrogen must be extracted from sources like coal or water, which can be an expensive and energy-intensive process. Another reason why electric cars are more common is that they can work with existing infrastructure – recharging can be as simple as plugging a car into the national grid – while hydrogen cars need specialised supply networks and stations to supply the gas for refueling.

Regarding your second question, gamma rays are the most energetic form of electromagnetic radiation. They are able to penetrate cells and collide with the molecules within them. If the rays collide with DNA in the nucleus, it can cause mutations or – at high enough doses – kill the cells outright.

The science of sunglasses

Dear **HIW**,
I have a question about how light reacts with materials. My sunglasses are purple on the front but yellowish-grey when I look through them from the back when I put them on. Is there a coating on the front side? How do I not see the purple colour on the other side?
Thanks for your time on my question.
Best regards,
Andy Shek

Your sunglasses look different from the back and the front due to all the different layers used in the lenses. The purple colour you see on the front comes from the number of different materials used to protect your eyes, including an anti-reflective covering, a polymer coating to reduce scratches and a polarising film to reduce glare. These lenses reflect purple light, which gives them their colour, but when you look through your sunglasses this light and similar shades don't reach your eyes, making the world appear yellow.


The types of tints used in sunglasses are used for different outdoor activities and sports

WIN!

AMAZING PRIZE FOR LETTER OF THE MONTH!

A BUNDLE OF THREE SCIENCE AND TECH BOOKS PACKED FULL OF COOL FACTS:

- 50 Greatest Wonders Of The World
- Engineer Academy
- Eureka! An Infographic Guide To Science

What's happening on... Twitter?

Make sure you follow us **@HowItWorksmag** for amazing facts, competitions and the latest in science & tech!

@rainbowxgran3
#great for the enquiring mind xx

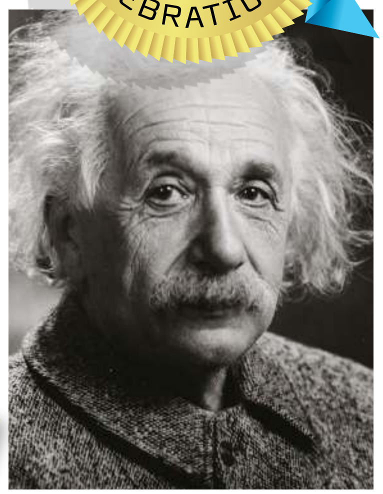
@greekLuis
Shout out to the profilers and statistic makers for rerouting me from learning about cars #uber @HowItWorksmag

@Astro_Jonny
I was almost there at the beginning! Joined this mag on issue 13, stayed for about 25. Time flies, eh.

@Dany_Johnston
Facts for your #horror #writing Delve inside a torture chamber #amwriting @HowItWorksmag

@JRfromStrickley
Really pleased & proud that our youngest lad Chris got 'letter of the month' in the latest @HowItWorksmag #buddingscientist

@MarsCuriosity
Happy #MartianNewYear! Should auld acquaintance be forgot? No way. Can't wait to share exploration with you on this next trip around the sun



Inside the mind of a genius

Dear **HIW**,
I have a question for your letters page: is it true that scientists still have Einstein's brain? Have they learned anything from studying it?
Thanks,
Heather Marshall

It's true! After the eminent physicist's death in 1955, Dr Thomas Harvey, the pathologist who conducted the autopsy, removed and preserved Einstein's brain for scientific study. He measured and photographed the brain, commissioned illustrations, oversaw its division into 240 separate blocks and prepared hundreds of slides containing tissue samples. He sent the samples to neuropathologists, who surprisingly found the samples to be no different to 'normal' brains. The brain's weight was actually very slightly lower than average for a man of Einstein's age.

Later studies on the samples found that Einstein had a higher than average ratio of glia (the brain's supporting cells) per neuron; the neurons in his prefrontal cortex were more tightly packed; and his inferior parietal lobule (which plays a role in mathematical thought) was wider than average. More recent studies of Harvey's photographs also revealed that Einstein had a thicker corpus callosum – the area of the brain that connects the left and right hemispheres. While these findings are interesting, it is not certain whether they are features he was born with or whether his brain was shaped by experience as he grew up.

"Hydrogen must be extracted from sources like coal or water, which can be an expensive process"

Get in touch

Want to see your letters on this page? Send them to…

How It Works magazine @HowItWorksmag howitworks@futurenet.com

Wendy Tremain and her son

Finlay Dean

Callum Pirson

Anish Mariathasan

Reader collections

You sent us in snaps of your How It Works collections to celebrate the release of the 100th issue!

Cosmo MacLellan

George Hampton

What's next?

We asked you what you wanted to see in future issues of the mag…

@ElstonDrew
@HowItWorksmag An article explaining sugar in the foods we buy and the ones to avoid & ones that are safe. There are too many confusing articles

@Joelllett
@HowItWorksmag anything sustainable/renewable energy related! Solar roads, desalination, home recycling. Any new ideas out there :)

@StephenParry80
@HowItWorksmag High-speed rail technology, please.

@GrahamSouthorn
I'm sceptical about delivery drones/robots. What do they do when they get to your house, assuming you're not in?

We love this brilliant shot from Aussie reader Max!

"G'day mates, I'm from Down Under so I always read my How It Works magazines upside down! I love them. Keep up the good work."

WIN THIS MEGA BUNDLE

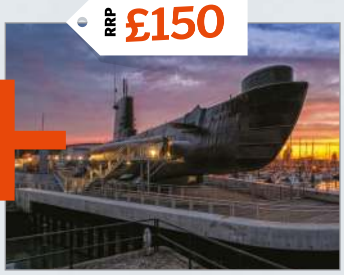
ENTER OUR PHOTO CONTEST FOR YOUR CHANCE TO WIN THIS GREAT SELECTION OF PRIZES

WORTH OVER £2,500!

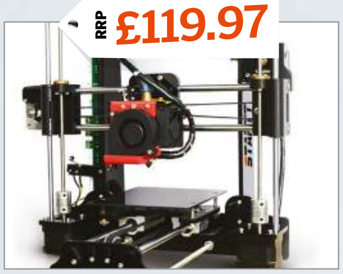
HOW TO ENTER

All you need to do to be in with a chance to win is to send us a photo of yourself or a family member holding your copy of this issue!

Email your entries to **howitworks@fut**



Portsmouth Historic Dockyard 2x family tickets+
Visit all 11 attractions at Portsmouth Historic Dockyard, including the Mary Rose, HMS Victory and HMS Warrior.



3D printer
You can join the printing revolution with your very own 3D printer!

2x K'NEX Power & Play Building Tubs
Unleash your inner engineer with the brand new K'NEX Power & Play Motorized 50 Model Tub, with more than 530 pieces in a reusable storage box!

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- For full terms and conditions, please visit: www.futuretcs.com
- The competition is open to UK and US residents only (some state exclusions apply, see link above for details).
- The competition closes at 00:00 GMT on 13 July 2017.
- By entering, you give How It Works your consent to use the submitted photo in a future issue, and to pass on your contact details to prize providers for delivery.
- Readers under 18 must ask permission from a parent or guardian before entering.
- Competition entries will be accepted by emails to howitworks@futurenet.com only.
- Entries submitted after the closing date will not be considered.
- Entries via www.howitworksdaily.com, Facebook or Twitter will not be considered.
- The winner will be chosen at random.
- *Science Museum tickets are valid for the Robots exhibition which runs until 3 September 2017. For more information, visit beta.sciencemuseum.org.uk/robots
- +Portsmouth Historic Dockyards tickets will be valid for one year from the day they are sent out and are available for the entire Dockyard. Not valid for special ticketed events, please see website for details: www.historicdockyard.co.uk
- §Winchester Science Centre family ticket is valid for 2 adults and 2 children for general admission. General admission tickets allow full access to the hands-on exhibition area during normal opening hours. General admission does not include admission to events or the planetarium. For information about events visit www.winchestersciencecentre.org/visitor-information/whats-on
- ✷ Prices converted from euro to pound sterling, correct as of 30th May 2017

CLOSING DATE: 00:00 GMT ON 13 JULY 2017

urenet.com with the subject heading HIW100

Nearly 2,000 new plant species were discovered in 2016

A recent report from The Royal Botanical Gardens at Kew highlights just how much we still have to learn about Earth

Over 100 scientists from 12 countries across the world took part in creating Kew's second annual *State Of The World's Plants* report, which aims to help discover, classify and safeguard the huge range of flora on our planet.

The most recent assessment, conducted during 2016, includes 1,730 plant species that are new to science. The discoveries include previously unknown relatives of the aloe vera plant, five new species of the manihot in Brazil (which is related to cassava and tapioca plants) and a new type of parsnip in Turkey. These findings are important, as new plants could have the potential to be used as food crops, medicines or timber, reducing the strain currently exerted on existing sources.

Professor Kathy Willis, director of science at the Royal Botanical Gardens at Kew, explains: "Plants are the foundation of the world's ecosystems and hold the potential to tackle some of our most pressing issues, as we try to strike a delicate balance between our needs and those of the natural world. We've tried to make sure that this year's *State Of The World's Plants* report goes beyond the numbers to look at the natural capital of plants – how they are relevant and valuable to all aspects of our lives."


The *Tibouchina rosanee*, a newly discovered species of 'princess flower', was found in Brazil


29 new species of begonia were found in Borneo

"1,730 plant species new to science were discovered last year"


The *Pastinaca erzincanensis* is a new species of parsnip discovered in Turkey

These spiky flower clusters (above) belong to *Sokinochloa australis*, a new genus discovered in Madagascar. *Sokina* is Malagasy for 'hedgehog', which they resemble (below)

This new type of orchid was found in Cambodia

The flowers of the *Paubrasilia echinata* feature a characteristic red upper petal

The *Englerophytum paludosum* is one of four new species of its genus discovered in central Africa

The *Commincarpus macrothamnus* shrub was found in eastern Ethiopia

The report by numbers

The incredible figures behind the world's fantastic flora

80%

of the food we derive from plants comes from just 17 different plant families

225

plant species have had their whole genomes sequenced

28,187

plant species are recorded as being used for medical purposes

The Paris japonica plant has

50x

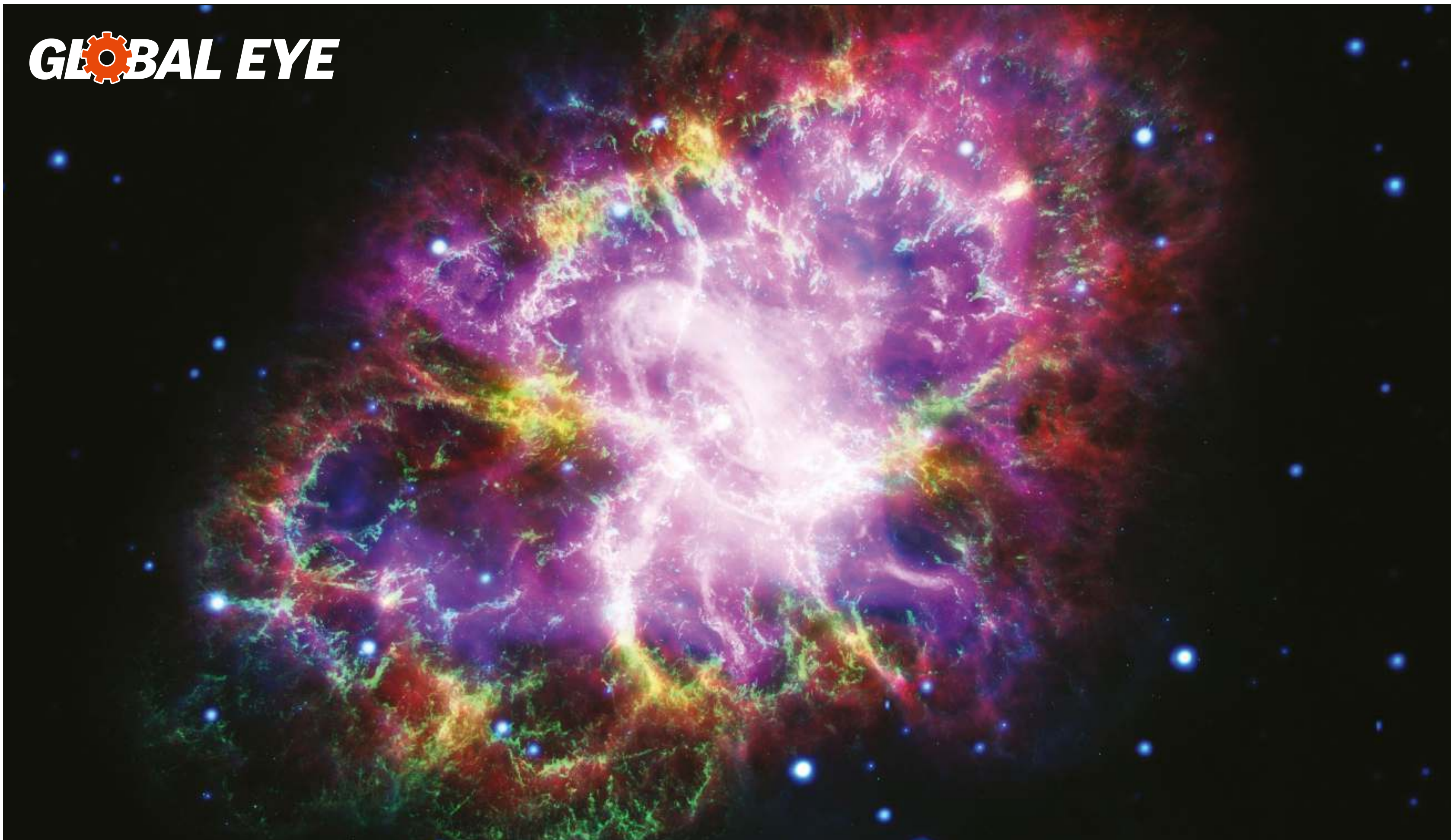
more DNA in its genomes than a human due to its chromosomes being so big

6,075

plant species are classified as invasive

340mn

hectares of the world's vegetated surface burns each year



OBSERVATORIES JOIN FORCES TO STUDY THE CRAB NEBULA

Data from orbital telescopes and ground arrays have been combined to produce this stunning image

The Crab Nebula is a supernova remnant approximately 6,500 light years away from us. Recorded by Chinese astronomers in 1054, the supernova that created it was so bright it was visible from Earth.

This beautiful image of the nebula was produced by combining data from five different telescopes: the Karl G Jansky Very Large Array (VLA), Spitzer Space Telescope, Hubble Space Telescope, XMM-Newton Observatory and the Chandra X-ray Observatory. Together, they span almost the entire electromagnetic spectrum.

The VLA is based in New Mexico, US, and consists of 27 25-metre-long radio telescopes that combine their data to effectively act like a single, 40-kilometre-diameter dish. Images of the crab nebula collected using the array in 2012 were combined with data from the space telescopes to create this colourful composite.

The bright centre reveals a pulsar – an incredibly dense neutron star rotating once every 33 milliseconds, emitting beams of radio and light waves. The intricate web of clouds radiating out from the centre of the nebula is created by interactions between material ejected during the supernova and the 'wind' of charged particles streaming out from the pulsar.

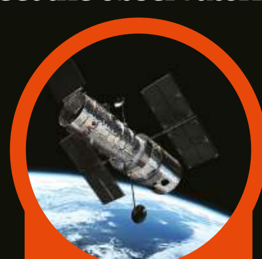
Gloria Dubner, lead scientist of the team that studied the telescope data, has revealed that this team effort is already providing new insights and helping to unravel the physics of the nebula.

"Comparing these new images, made at different wavelengths, is providing us with a wealth of new detail about the Crab Nebula. Though the Crab has been studied extensively for years, we still have much to learn about it."

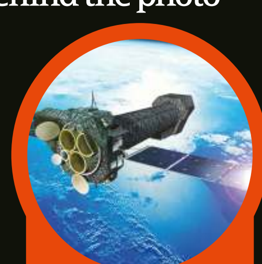
TELESCOPE TEAMWORK Meet the observatories behind the photo

Very Large Array
Location: New Mexico
Detects: radio waves
Colour in image: red

Spitzer Space Telescope
Detects: infrared
Colour: yellow



Hubble Space Telescope
Detects: visible light
Colour: green



XMM-Newton
Detects: ultraviolet
Colour: blue

Chandra X-ray Observatory
Detects: X-rays
Colour: purple

NEWS BY NUMBERS

7

The number of *Bond* films in which Sir Roger Moore played the legendary spy

Over 200,000

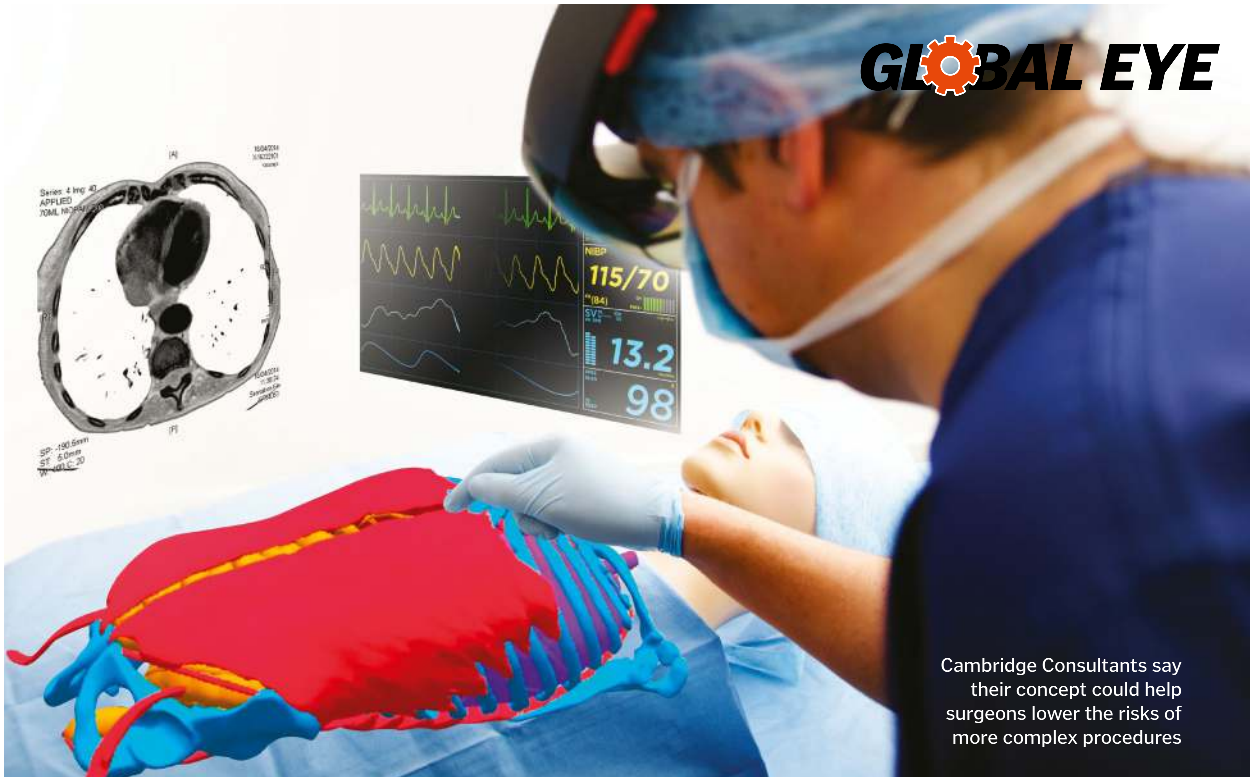
The number of computers infected by the WannaCry ransomware attack

1913

The year the first Royal Horticultural Society Chelsea Flower Show took place

14x

How much faster a snail is than a standard soft-soil tunnel boring machine – a rate that Elon Musk hopes to beat when creating tunnels with The Boring Company



Cambridge Consultants say their concept could help surgeons lower the risks of more complex procedures

Augmented reality can aid surgery

Could AR soon be making its way into the OR?

Augmented reality (AR) tech has plenty of applications (find out more on page 25), and it could soon play a role in surgical procedures.

A concept from product design and development firm Cambridge Consultants showcases how surgeons could use Microsoft's HoloLens to see inside patients in real time. By using data from patients' body scans, the system could create holographic 3D representations of their tissues and organs, providing an interactive view inside the patient during surgery.

This concept could revolutionise surgery and allow more minimally invasive procedures to be performed.

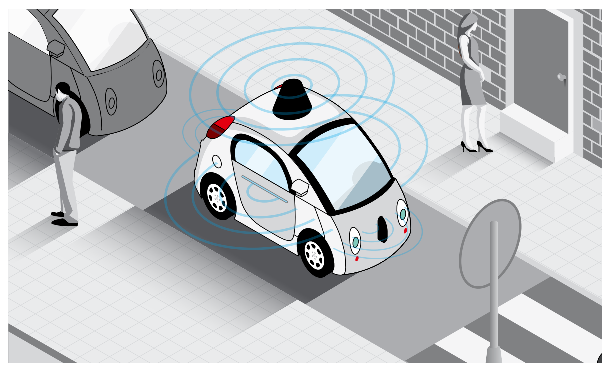
Scientists find 40 more 'intelligence genes'

Study sheds light on how our DNA might influence our intelligence

Results from a Dutch led study suggest that there is a link between certain genes and our intelligence.

Looking at the genetic profiles and IQ test scores of nearly 80,000 individuals, the team found evidence to suggest that 52 genes – 40 of which were new discoveries – are linked to the biological mechanisms of intelligence. The genes are involved in cell development, synapse formation, axon guidance and neuronal differentiation and are mostly expressed in the cells of the brain tissue.

However, studies of this nature can be quite controversial, as the IQ tests the data is based on do not usually account for other intellectual abilities such as creativity or social intelligence.



Less stop-go traffic with driverless cars

Self-driving vehicles also cut the risk of accidents and increase fuel efficiency

A study by the University of Illinois College of Engineering in the US has found that even having just a few driverless vehicles on the roads could lead to a substantial reduction in traffic problems.

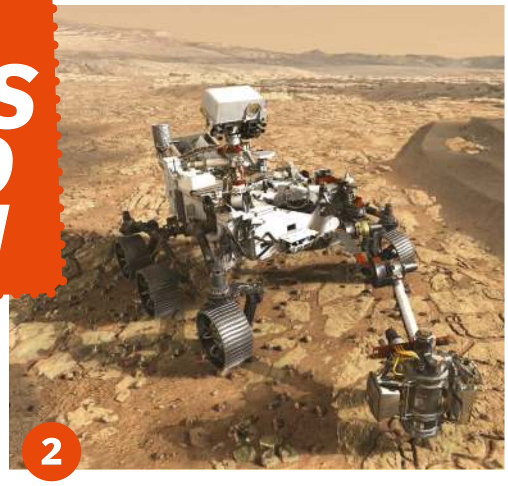
It is thought that driverless cars benefit other road users because their careful, smooth pace improves traffic flow. The team's data suggests that, even if only five per cent of vehicles on the roads were autonomous, there would be fewer incidences of stop-go traffic and fuel consumption would be reduced by as much as 40 per cent.

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

1 German scientists have built the largest artificial sun

The German Aerospace Center's DLR facility is home to the Synlight project, a huge array of 149 xenon lamps that can mimic sunlight. It can be used to simulate a constant, reliable solar source. Researchers are using Synlight to help accelerate research into solar fuels.



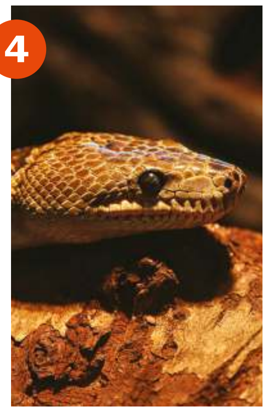
2 Here's what the Mars 2020 rover will look like

NASA released this artist's concept of their next Mars rover, which will expand our search for life on the Red Planet. Like its predecessors, Mars 2020 will look for signs that Mars was once habitable, but it will also be able to search for evidence of past microbial life itself.

3 Ancient beads were space rocks

Analysis of beads found in a 2,000-year-old Native American grave in modern-day Illinois show that they were made from shards of a meteorite.

4 Snakes coordinate hunts



It was previously thought that snakes hunt and eat alone, but new evidence suggests that some species work together to catch prey. Cuban boas have been seen positioning themselves to form a wall across cave entrances so they can catch as many passing bats as possible.

5 Flamingos save energy

When flamingos stand on one leg they expend less energy compared to when they are standing on both. This balancing act requires no active muscular effort, so the birds can even snooze this way.

6 Beauty sleep is real

A new study has shown that a few bad nights' sleep can make people appear less attractive to others, compared to when they have had a good night's rest. Lack of sleep can make people look unhealthy, so it's thought that this might trigger a subconscious disease-avoiding response, making us want to stay away to avoid potentially getting ill.

7 'Fat but fit' is a myth

It had previously been thought that people could be obese but medically fit, but new research contradicts this. A study that looked at medical records of millions of UK patients found that obese individuals were more likely to develop heart disease, or suffer from strokes or heart failure, than those of a healthy weight.

8 Trees might make summer air pollution worse

It may seem counterintuitive, but under some circumstances plants may actually contribute to air pollution. During a heat wave, trees can produce volatile organic compounds (VOCs), which can make air pollution – especially ground level ozone – up to 60 per cent worse. The trees' VOCs themselves aren't dangerous, but in the air they react with nitrogen oxides produced by vehicles. These compounds can contribute to a variety of health problems, from respiratory issues to heart attacks.

9 Elon Musk is boring

The tech entrepreneur is making progress with his latest venture, The Boring Company. Musk hopes to make the tunnel boring process faster and more cost-effective.

10 Mushrooms are better microwaved

Researchers found that microwaving or grilling the fungi increases the levels of antioxidants, while boiling or frying reduces them.


FEED YOUR MIND WITH...
100 WONDERS
CELEBRATING THE INCREDIBLE WORLD AROUND YOU
Welcome to our rundown of the most amazing sights, discoveries, inventions and phenomena on this planet and beyond!

AMAZING EVERYDAY TECHNOLOGY

We take them for granted, but modern life depends on these incredible discoveries and inventions

Electricity

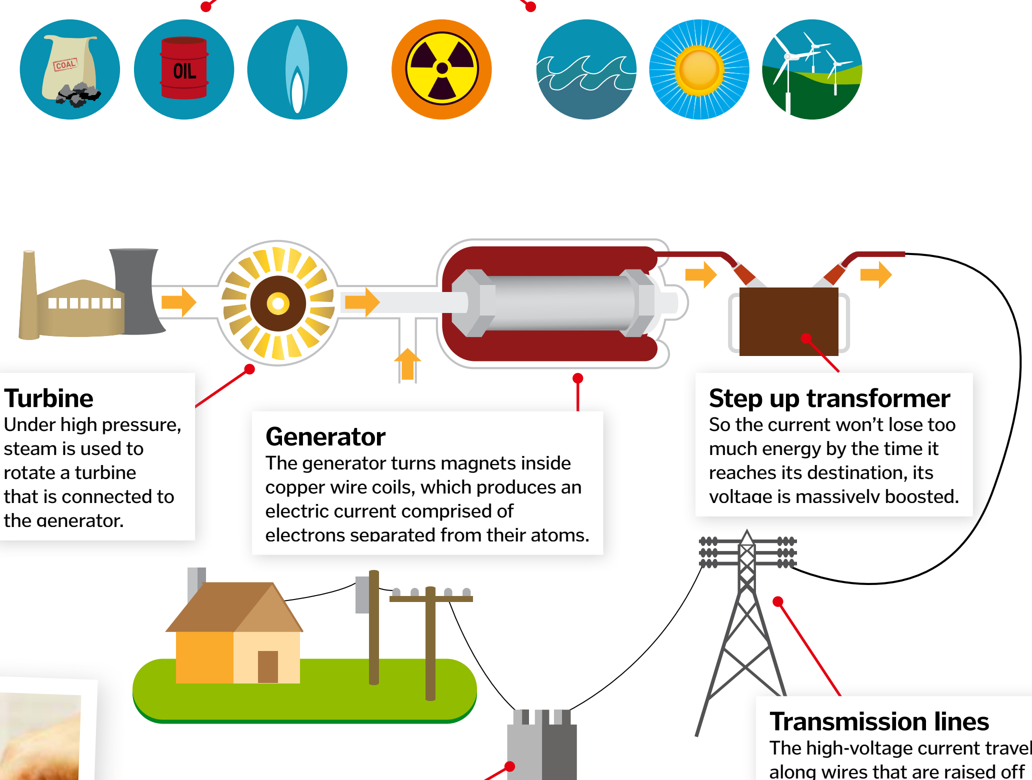
By discovering how to manipulate the flow of electrons, we triggered a technological revolution

01 Almost everything we do in our lives relies on electricity. Without it, our homes would be colder in winter, our food would go stale quicker, there would be no factories to build planes, trains and automobiles, no TV, circuit boards, AEDs or other high-tech medical equipment, and we wouldn't be reachable 24-7 on our mobile phones. We therefore have a lot to thank electrons for. As they zip across a conductor from a negatively charged object to a positively charged one, these subatomic particles create the electric currents that power the modern world's technological progress.

Despite what our amazing gadgets can do, we'd literally be powerless without electricity

Power stations

Discover where the power we can get at the flick of a switch comes from



Energy sources
Power stations burn fossil fuels (coal, oil or gas), or use the heat from nuclear fission, to produce steam. Kinetic energy from wind and waves can be harnessed to power generators directly. Solar panels can convert solar energy to electricity directly via the photovoltaic effect.

Turbine
Under high pressure, steam is used to rotate a turbine that is connected to the generator.

Generator
The generator turns magnets inside copper wire coils, which produces an electric current comprised of electrons separated from their atoms.

Step up transformer
So the current won't lose too much energy by the time it reaches its destination, its voltage is massively boosted.

Transmission lines
The high-voltage current travels along wires that are raised off the surface by poles and pylons, or buried underground.

Step down transformer
The current's voltage is stepped down again to avoid blowing up devices when it flows into them.

"Almost everything we do in our lives relies on electricity"

Artificial light

Our mastery of fire and electricity has led to illuminating innovations that enhance and save lives

02 Although electricity powers our TVs, monitors and mobile phones, these devices are only useful because pixels in their screens produce light. The electrically charged organic compounds hidden under cutting-edge displays are a long way from the open flames we once used on candles and gas lamps. Yet heat and other chemical reactions are still used in incandescent and fluorescent bulbs to light up homes and businesses and make streets safe at night. Other important things we can do by controlling photons include taking photos and helping surgeons to see deep into our bodies where clots and cancer could be hiding.

Harnessing light adds colour to life and lets us work and play into the night

c. 1 million BCE Homo erectus uses fire to produce heat and light.

500 BCE Romans make early wicked candles from animal fat.

1500s France's government requires Parisians to light lanterns outside their homes.

1878 Thomas Edison's Electric Light Company starts developing electric light bulbs.

1962 General Electric engineer Nick Holonyak Jr. develops the first red LED.

2011 Harald Haas proposes LiFi as a light-based means of transmitting data.

Water treatment

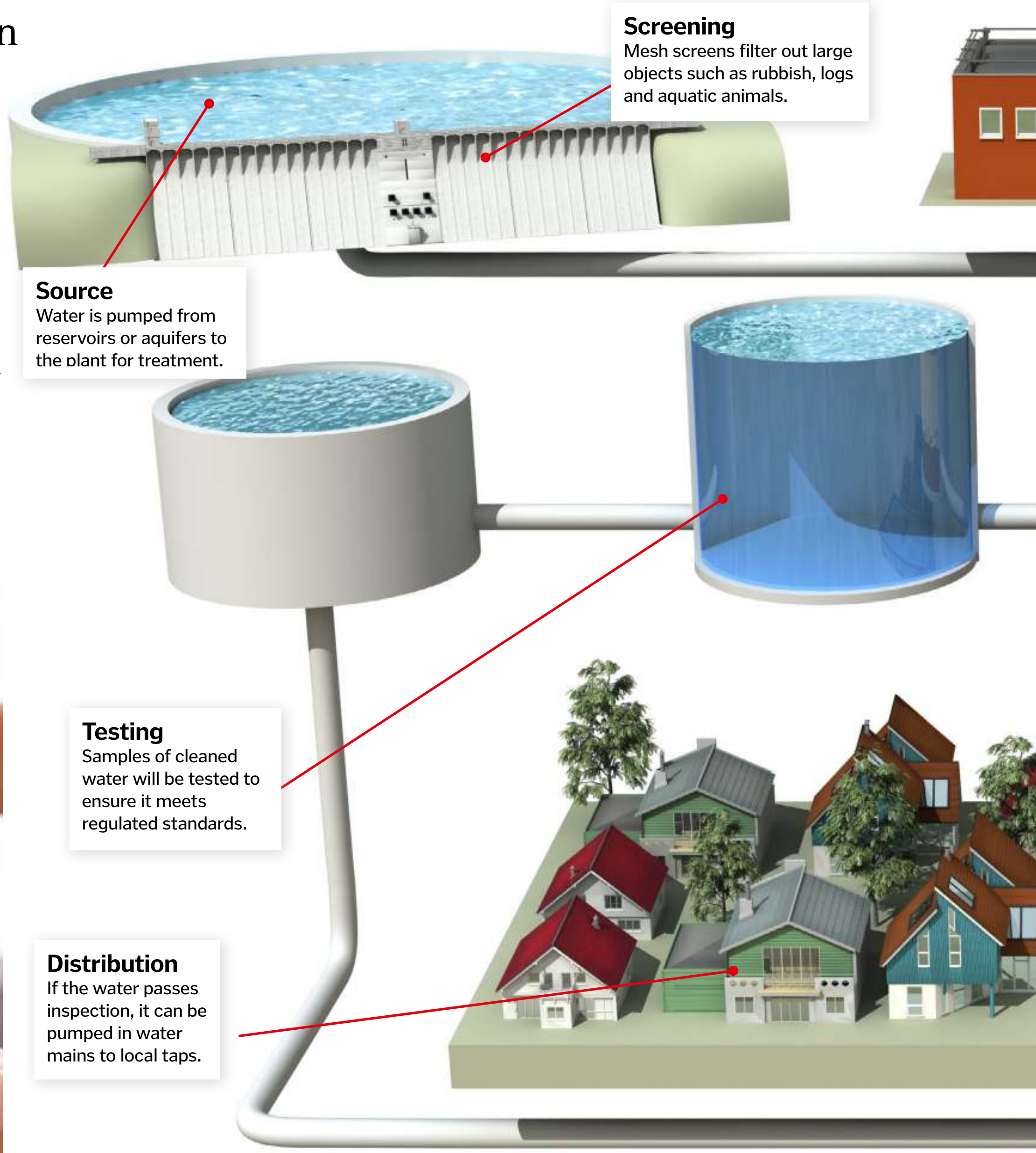
Giving water a thorough clean before it enters our homes helps us live healthier lives

03 Water that is pumped through mains pipes to our taps has generally been drawn either from reservoirs or underground aquifers. Before it becomes drinkable, however, it is subjected to processes that include filtration, flocculation, sedimentation and possibly fluoridation to remove dirt, debris, invertebrates, fish, potentially harmful bacteria and bad smells. Bottled water sold in shops also needs to conform to regulated health and safety standards. Accordingly, it may be filtered or chemically treated and even be derived from municipal tap water supplies.

Having clean water on tap protects us from water-borne diseases such as cholera

Municipal water treatment

Discover how a treatment plant gives water the works to ensure it's safe to drink



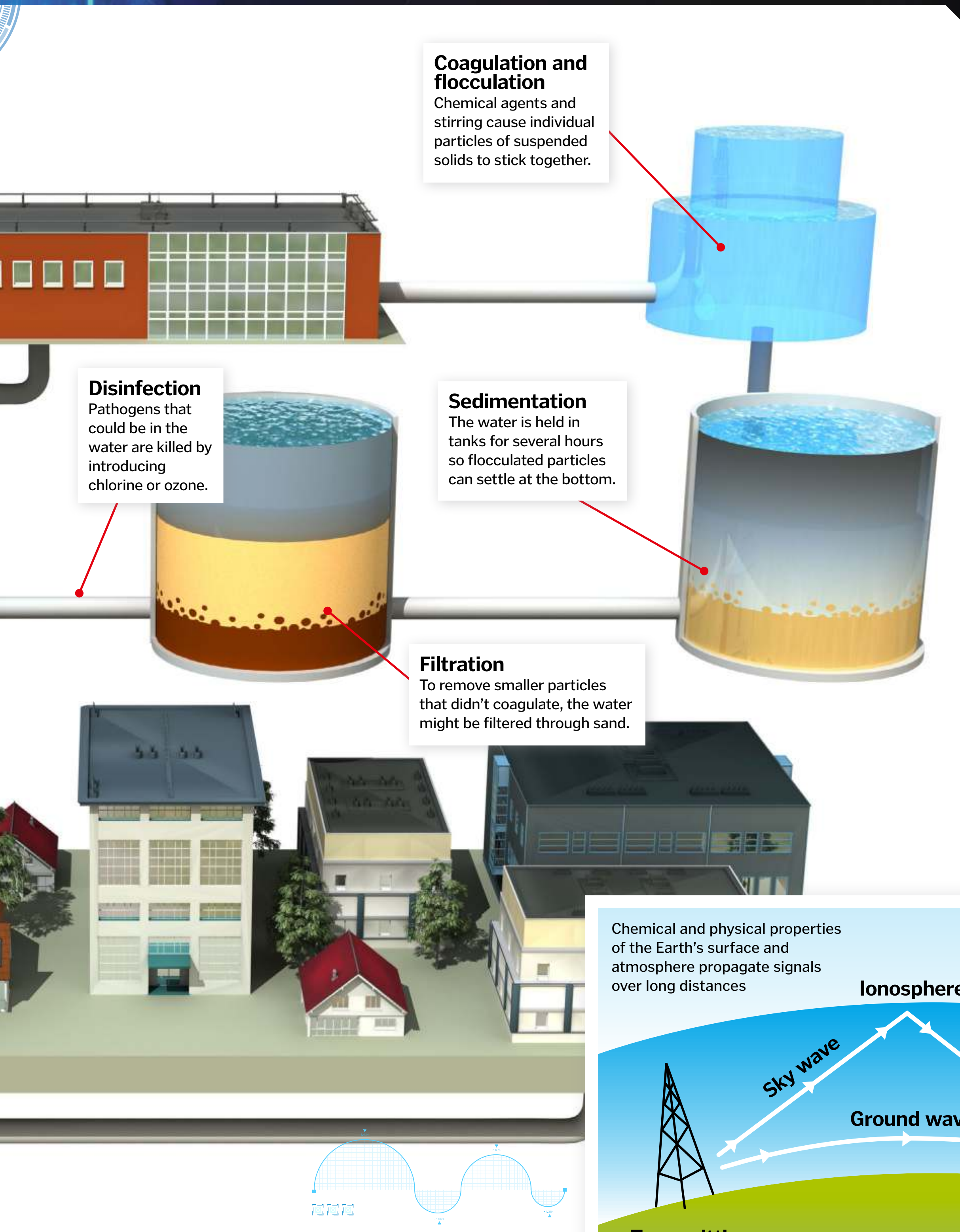
Global positioning systems

Getting lost is almost impossible now that everyday devices are always receiving signals from space

25%

04 Thanks to the affordability of GPS receivers and an extensive satellite network that began as a US government defence strategy, we can now pinpoint our location almost anywhere at any time. Wearables, mobile phones and other GPS devices do this by measuring how long it takes for signals to arrive from three or more satellites. Knowing a precise location is vital for emergency and rescue services, pilots, navigators and air traffic controllers. Using GPS coordinates to target weapons can reduce civilian casualties. It has also made operating remote equipment easier and safer in industries such as mining and agriculture.

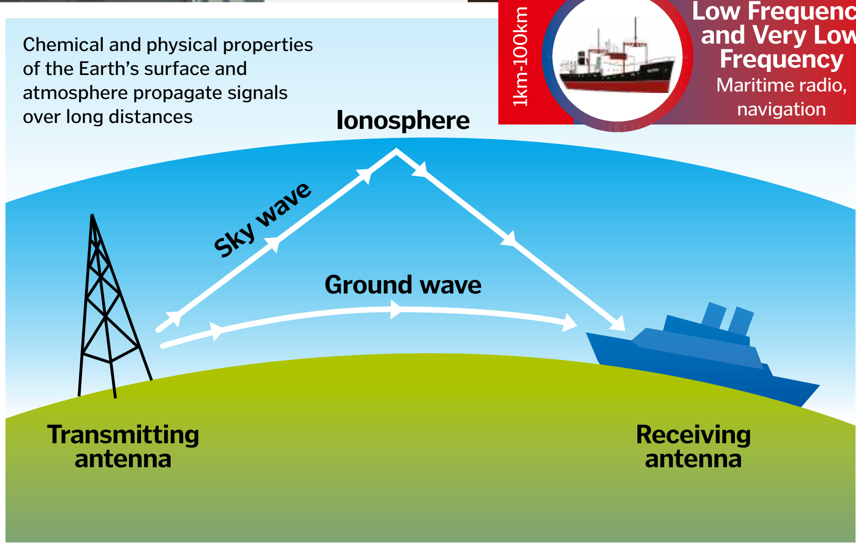
GPS and accurate mapping software have made sat-nav systems popular



Highs and lows of radio

The varying levels of radio frequency have many uses

- **0.1mm-1cm — Extremely High Frequency:** Radio astronomy, satellite comms
- **1cm-10cm — Super High Frequency:** Satellite comms, Wi-Fi
- **10cm-1m — Ultra High Frequency:** UHF TV, mobiles, GPS, Wi-Fi, 4G
- **1m-10m — Very High Frequency:** VHF TV, FM radio
- **10-100m — High Frequency:** Shortwave radio
- **100m-1km — Medium Frequency:** AM radio, aviation radio, navigation
- **1km-100km — Low Frequency and Very Low Frequency:** Maritime radio, navigation



Radio transmission

Our uses for nature's hidden transmissions now go far beyond what we can hear

05

Radio is a natural phenomenon that we exploit using transmitters and receivers. The former intensifies the electromagnetic radiation produced by moving particles and beams it over the air as waves. Receivers intercept and interpret these waves as sounds, images or other data based on factors such as frequency. Shortwave signals travel long distances because they are reflected back to Earth by the upper layers of the ionosphere. Signals in longer wavebands travel within the troposphere closer to the ground and are deflected by spatial differences in factors such as temperature, pressure and humidity.

> *"Transmitters beam electromagnetic radiation over the air as waves"*

The internet

The interconnectedness of modern computers is so essential, it's hard to imagine life without it

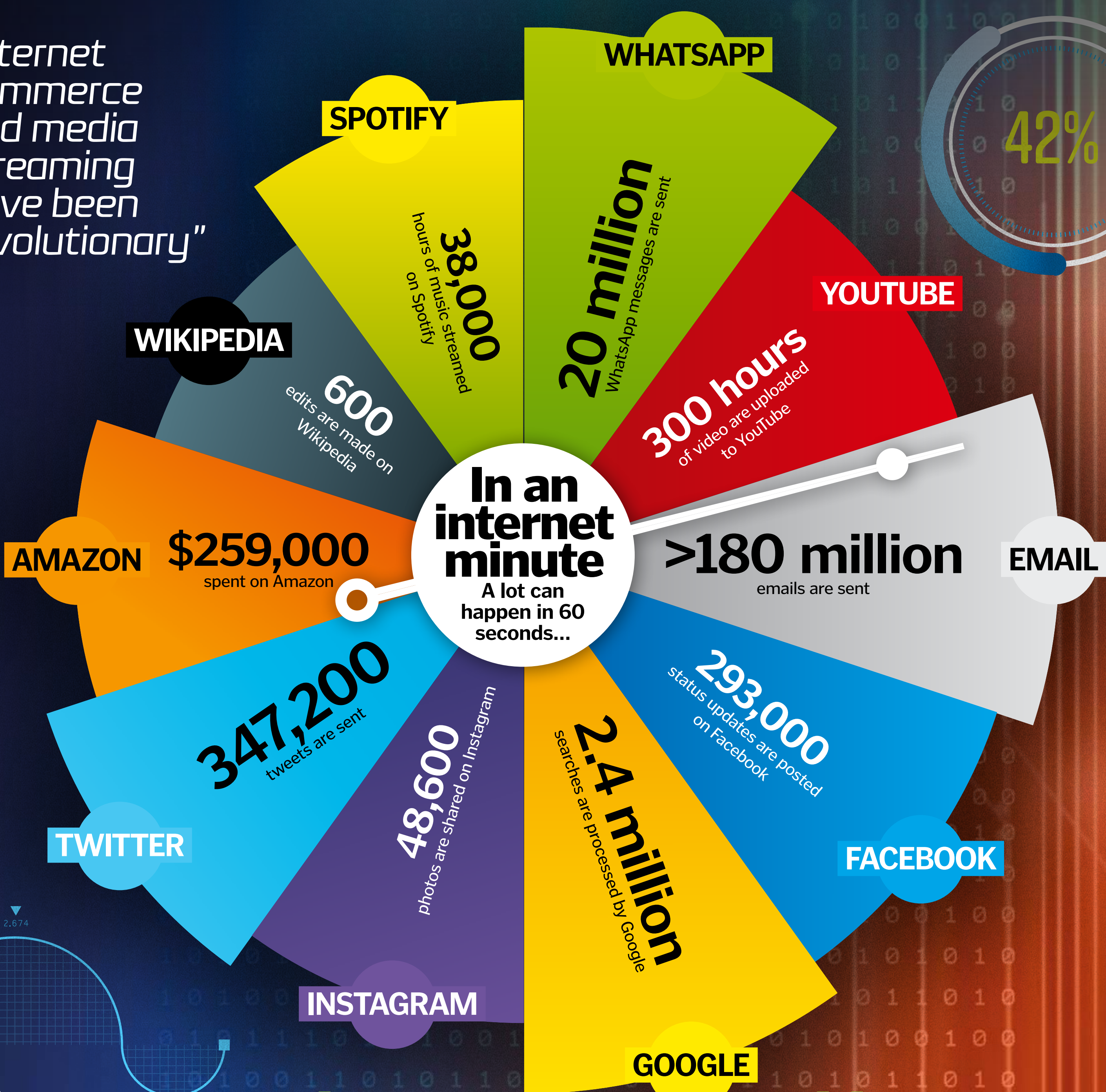
06

A network of geographically distant computers was originally proposed in the 1960s by MIT computer researcher JCR Licklider. The earliest form, ARPANET, was limited to just a few nodes in the US, but the development of packet switching and TCP/IP protocols (internet communication 'languages') in the 1970s unlocked the network's potential for expansion around the world.

E-mail was being used by the 1980s, but it wasn't until Tim Berners-Lee introduced the World Wide Web in the early 1990s that the internet began to spread beyond research and government institutions. Since then, improvements in security, data transmission speeds, server technology and mobile access have allowed individuals and organisations to store and access ever-increasing amounts of data and send big files at faster speeds from anywhere. Meanwhile, internet commerce and media streaming have revolutionised shopping, publishing, music and visual media, while activities such as banking, online voting, social networking and, unfortunately, cybercrime have become commonplace.

Web giant Google has seen off other search engines such as AltaVista and Ask.com

"Internet commerce and media streaming have been revolutionary"



Lasers

Far from being the stuff of science fiction, this light-based technology is all around us

07 Light Amplification by Stimulated Emission of Radiation (LASER) describes a process whereby electrons are excited inside atoms through the application of an energy source such as an electric current or another laser. Once excited, the electrons jump to a higher-energy orbit around the atom's nucleus. When they subsequently drop back to their normal ground state, they emit light as a confined stream of photons that are all at the same wavelength.

LASER APPLICATIONS

Surgery
Surgeons use lasers for cutting and repairing; the high-energy beam can slice like a scalpel, cauterise wounds and repair retinas.

3D scanners
Objects can be 3D-printed with high accuracy based on scans obtained by bouncing lasers off the surfaces along different planes.

Laser targeting
Laser designators mounted on guns or military vehicles can illuminate or pinpoint targets requiring a high degree of precision.

Fibre optics
Data travels along fibre optic cables encoded in photons. Because laser beams are highly focused, the signal decays less rapidly.

Barcode scanners
These identify stock by shining laser light on the lines in a barcode and interpreting the pattern reflected back.

Mobile phones

Originally a chunky luxury, these have become pocket computers that we can't leave home without

"Ever-smaller components have led to pocket-sized phones"

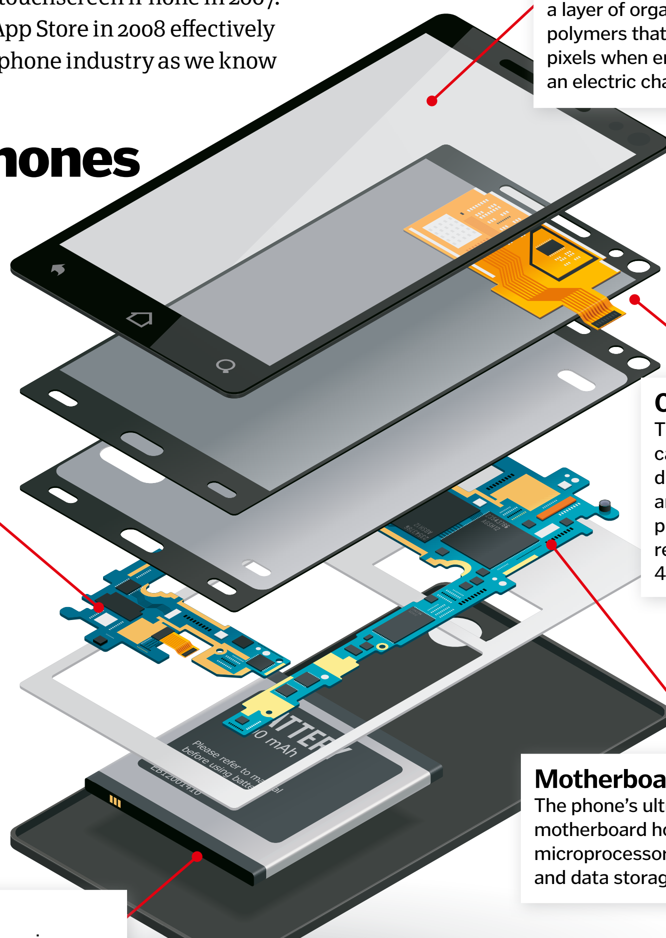
08 A 'Mobile Telephone Service' was introduced in America by AT&T in the 1940s, but its phones were hardly portable. The first commercially available mobile phone, Motorola's DynaTAC 8000X, arrived in the 1980s, but it was appropriately nicknamed 'The Brick' because it weighed 790 grams.

Installation of cell towers and the switch from analogue to digital communication in the 1980s made mobile networks feasible. Meanwhile, ever-smaller microprocessors, batteries and radio transmitters allowed manufacturers like Nokia to build pocket-sized phones. As consumers demanded more from mobile devices, companies such as Blackberry, Apple and Samsung began a race to innovate, leading to the release of the touchscreen iPhone in 2007. The opening of the App Store in 2008 effectively launched the smartphone industry as we know it today.

Incredibly, there are more mobile phones than people on the planet

Smartphones

The main features that make today's mobile phones indispensable



Touchscreen
AMOLED displays include a layer of organic polymers that light up the pixels when energised by an electric charge.

Accelerometer
This senses the phone's movement, allowing apps such as games and activity trackers to respond to the user's position.

Camera
The top smartphones can now have dual-lens cameras and some can take pictures at resolutions exceeding 40 megapixels.

Motherboard
The phone's ultra-thin motherboard houses the microprocessor, RAM and data storage chips.

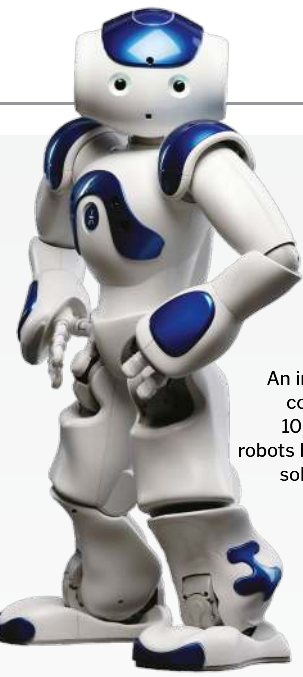
Battery
The latest lithium-ion batteries can hold a charge for more than a day and be recharged wirelessly.

Robotics

How machine learning is building adaptable robots

09 Robots are capable of performing fiddly, repetitive and dangerous tasks without tiring. At their most basic, they can be programmed to perform set functions according to rigid instructions, but with inspiration from biology, they are becoming increasingly capable of learning on their own.

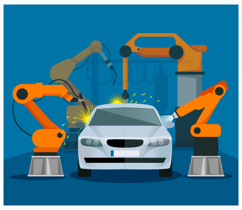
Artificial neural networks are software simulations that try to recreate the inner workings of the human brain. They are made from layers of inputs and outputs connected by a web of hidden units. Each connection is given a weight that dictates how strong it is and whether it sends an activating or deactivating signal to connected units. Each unit adds up all of the signals they receive and, if they reach a certain threshold, they 'fire' like a nerve, sending the signal further through the network. In reinforcement learning, when the machine gets something right, the weights between the connections are strengthened. If it gets something wrong, they're weakened. This allows robots to learn.



An interactive companion, 10,000 NAO robots have been sold globally

Everyday robots

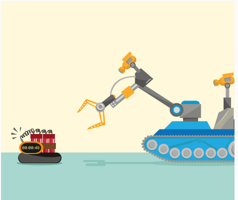
Robots are finding their way into every aspect of our daily lives



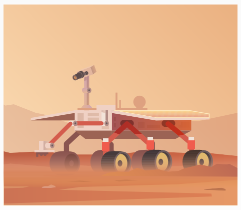
Manufacturing
Industrial robots can perform precision tasks repeatedly without tiring, replacing or supporting human workforces.

Drones
Unmanned aerial vehicles, or drones, allow flight into risky areas. They are equipped with sensors and piloted remotely.

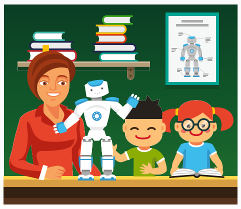
Healthcare
Robots in the operating theatre are able to assist surgeons with complex procedures by providing precision and control.



Military
Bomb disposal robots guided from a distance are equipped to fire high-pressure water to safely disarm explosive devices.



Space travel
Robots can venture to places too dangerous for us; from the outside of the International Space Station to the surface of Mars.



Education
Simple classroom robots are a tool for learning programming, allowing children and young people to tinker with their code.

Cameras

The devices that capture a moment in time by recording light

10 When you take a photo, you are capturing the light that reflects off the scene in front of your camera. That light enters the camera through the lens, a piece of curved glass that bends the light rays onto a single point to focus the image.

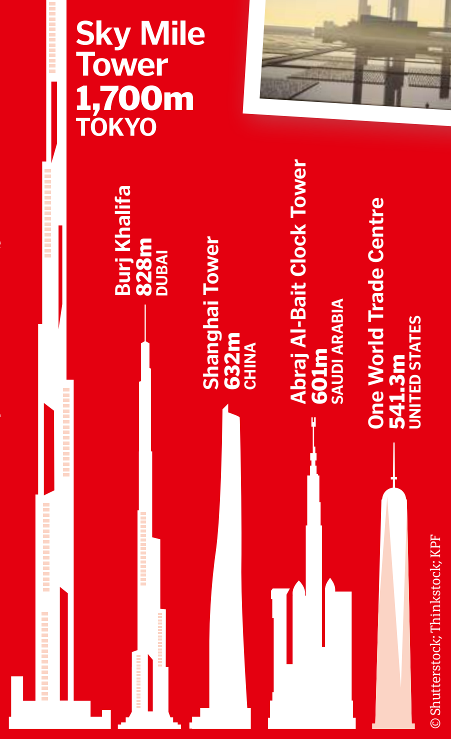
When you take a picture, a mechanical shutter inside the device opens briefly, allowing the light to reach the sensor or film. In a digital camera's sensor, the light is deconstructed into millions of dots of colour called pixels. This allows light to be converted into something that can be easily stored, as each pixel's colour and brightness can be measured and stored as a number. When the image is viewed later, each pixel is recreated from these numbers, which collectively look exactly like the original picture. In film cameras, the light reacts with the photographic film, creating a chemical record of the scene.

Skyscrapers

How innovative materials and designs have transformed city skylines

11 In the late 1800s, the development of mass steel production made building structures higher than ten storeys possible. Strong yet lightweight steel beams can support more weight than brick walls and are used to create a grid that forms the structure's skeleton. The vertical steel columns transfer the building's weight into the substructure below ground, which consists of cast-iron plates and horizontal steel beams resting on a concrete pad. This distributes the weight from the columns over a wider surface and anchors them deep in the ground. The outer walls then need only to support their own weight.

The Sky Mile Tower is due to be built by 2045



Virtual and augmented reality

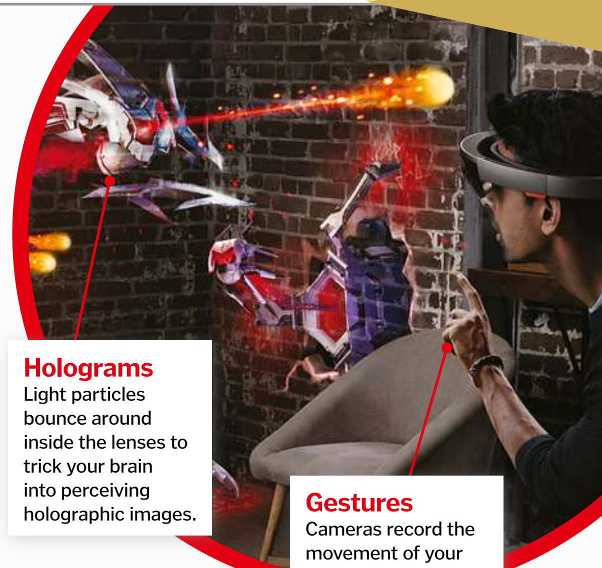
The immersive display technology with countless life-changing applications

12

Virtual reality headsets are the latest must-have gadgets taking the world by storm, enabling you to fully immerse yourself in a three-dimensional, 360-degree virtual environment.

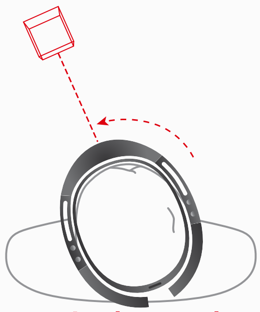
They work using sensors that can determine the orientation of your head and then adjust the display accordingly so you really explore the scene. Although they are currently marketed mainly at gamers who want to put themselves in the action, they also have enormous benefits for other industries, such as engineering and education. These benefits have led Microsoft to take the technology one step further, creating an augmented reality headset called HoloLens.

Instead of transporting you into an entirely digital world, this self-contained device projects holographic elements into the real one, allowing you to interact with virtual 3D objects and environments in your home or office.

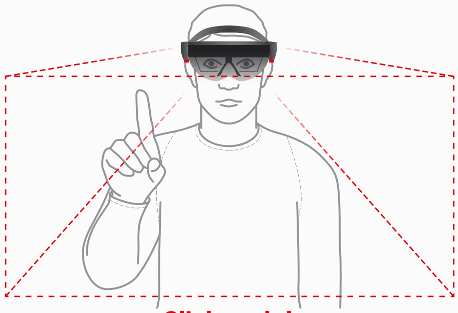


Holograms
Light particles bounce around inside the lenses to trick your brain into perceiving holographic images.

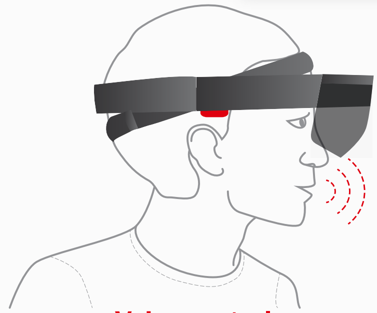
Gestures
Cameras record the movement of your limbs when they are in view, allowing you to control holograms with simple gestures.



Look around
A suite of sensors determines the orientation and tilt of your head, allowing you to move the cursor by adjusting your gaze.



Click and drag
Hololens allows you to click a hologram and then drag it to another location just as you would with a mouse.



Voice control
Microphones pick up voice commands, and speakers enable you to hear holograms wherever they are in the room.

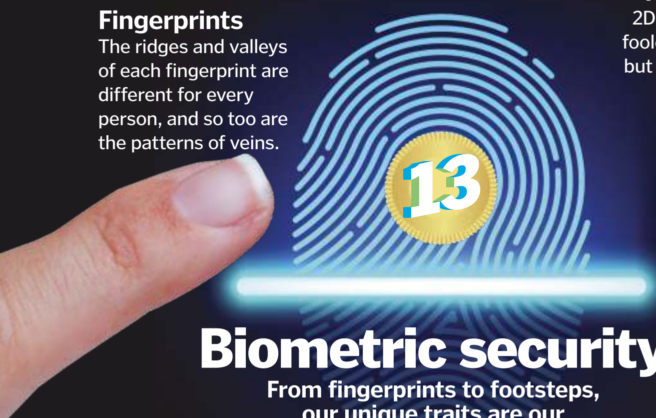
Biometric security

From fingerprints to footsteps, our unique traits are our biological passwords

13

Eye scans
The iris contains distinctive colours and patterns, while the retina has a one-of-a-kind network of blood vessels.

Facial features
2D recognition can be fooled by similar faces, but some features, like our ears, are completely unique.



Fingerprints
The ridges and valleys of each fingerprint are different for every person, and so too are the patterns of veins.

Gait analysis
Identifying faces in CCTV can be a challenge, but suspects can be narrowed down by telltale signs in the unique way they walk.

Voice recognition
Patterns of features like frequency and pitch can be extracted from audio recordings and used to create a 'vocal fingerprint'.

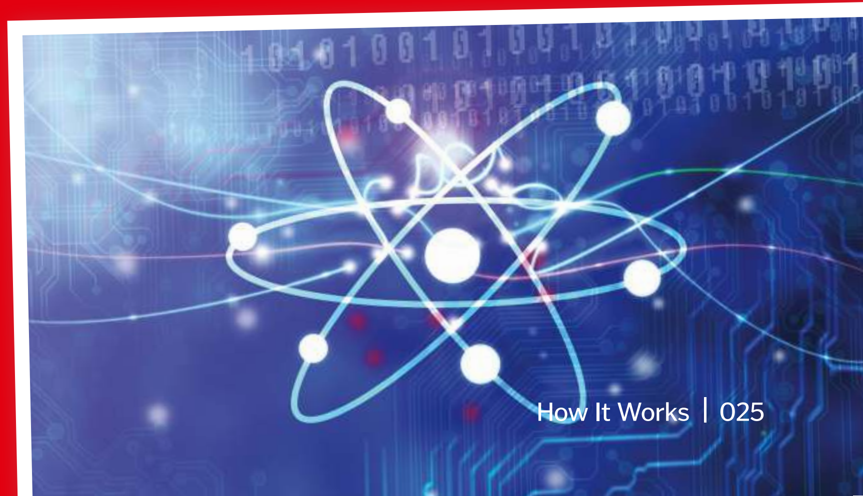
Quantum computers

The laws of quantum mechanics will create lightning-fast computers

14

Standard computers store information in 'bits' that can either be on or off, 1 or 0. Quantum computers, however, exploit the strange quantum physics of subatomic particles and store their information in 'qubits' (quantum bits).

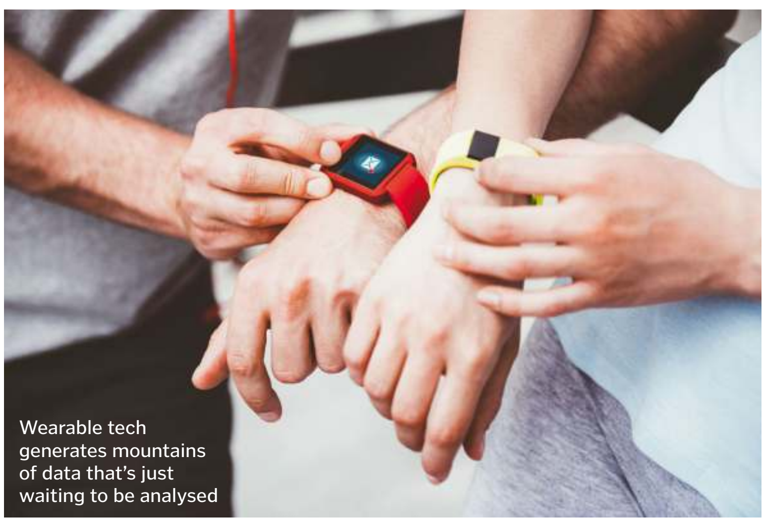
Subatomic particles can exist in multiple states, or 'superposition', which is fundamental to quantum mechanics. They can be on and off and everything in between, all at the same time. This means that they can run multiple calculations in parallel, completing thousands of computations in an instant.



Health tech

Advanced devices and apps are revolutionising the way we monitor our wellbeing

The latest hospital tech uses algorithms to predict when patients are at risk



Wearable tech generates mountains of data that's just waiting to be analysed

Vital signs

It's not possible for hospital staff to be at every patient's bedside around the clock, but it's crucial that changes to their vital signs are picked up as soon as possible. Current health tech does a good job of keeping people under surveillance, but the latest developments take monitoring to a new level. Devices like Snap40 and Vital Connect continuously track vital signs like heart rate, blood pressure, breathing and movement without wires. Worn on the skin as a band or patch, they can predict when someone might be at risk of deterioration, sending an alert to medical staff.

Activity analysis

Activity trackers have taken the world by storm. From Fitbit and Jawbone to Apple and Garmin, companies are now storing more data on our health than ever before. From tracking steps to monitoring your heart rate, these gadgets generate huge amounts of data, and not just for the people wearing them. Jawbone regularly digs into anonymised data gathered from their customers to analyse their eating, exercising and sleeping habits. Data from customers in the UK revealed disruptions in sleep when the clocks go forward, as well as on New Year's Eve and before the bank holidays.

Continuous glucose monitoring aims to replace finger prick blood sugar tests

The tech inside a smartphone can be used to monitor health at home

Blood sugar

Diabetes is a disease that affects the body's ability to make insulin (types 1 and 2), or make use of it effectively (type 2). Without a functioning insulin system, blood sugar can become too high, causing damage to nerves and blood vessels, or too low, causing a 'hypo', which can cause fatigue or even a loss of consciousness. Monitoring allows diet and insulin to be adjusted to keep blood glucose within a normal range.

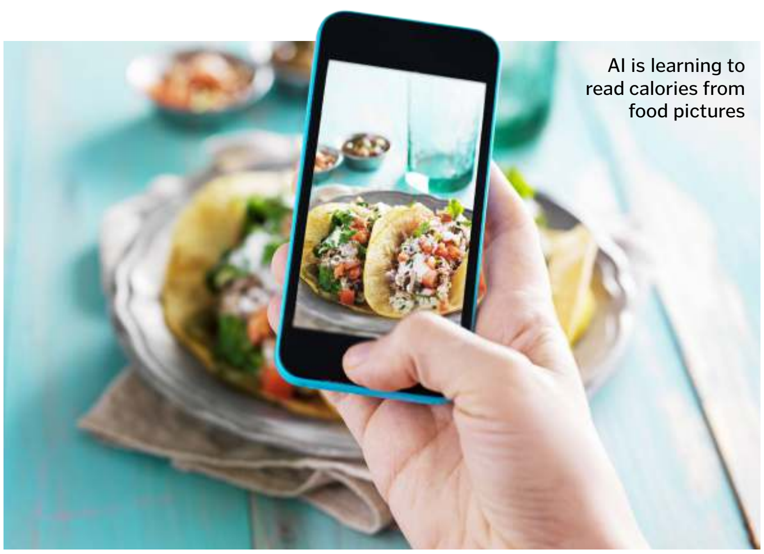
Glucose levels are normally checked by pricking the finger to get a small drop of blood, but this can be uncomfortable and doesn't give a continuous picture. The latest tech provides constant updates with a sensor that sits just under the skin. A small fibre is inserted into the tissue where it can measure glucose in the fluid. The data is stored in a patch and can be downloaded at any time via a scanner, allowing continuous monitoring.

Risk prediction

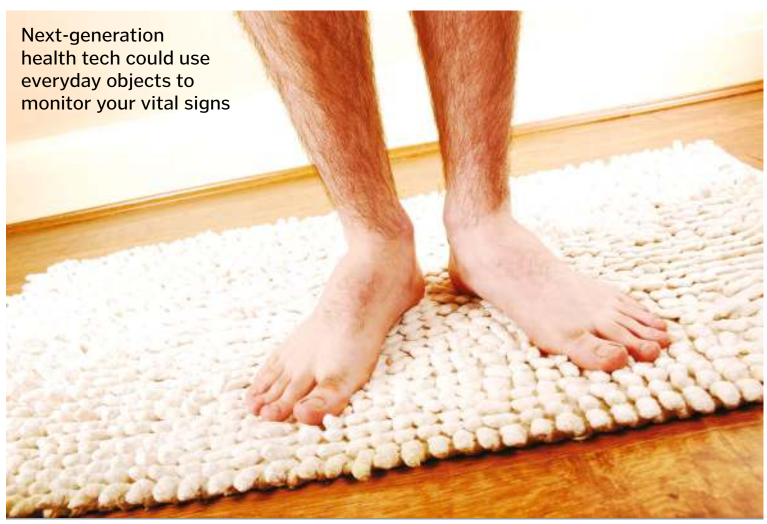
By combining and anonymising the data from thousands of patients it becomes possible to develop custom strategies to diagnose, monitor, treat and prevent disease. Helpfully, many of us carry a powerful research tool in our pockets: smartphone sensors, including the accelerometer, gyroscope, GPS, and microphone can all gather crucial data.

Apple's ResearchKit is a framework designed to help researchers gather medical data from apps, allowing people to remotely participate in research studies. Stanford has used the tech to create MyHeart Counts, an app that takes advantage of motion sensors to track activity for heart disease research. The mPower app uses a gyroscope to learn more about balance in Parkinson's disease. And the EpiWatch project adapts the Apple Watch to monitor and predict epileptic seizures.

"Many of us carry a powerful research tool in our pockets"



AI is learning to read calories from food pictures



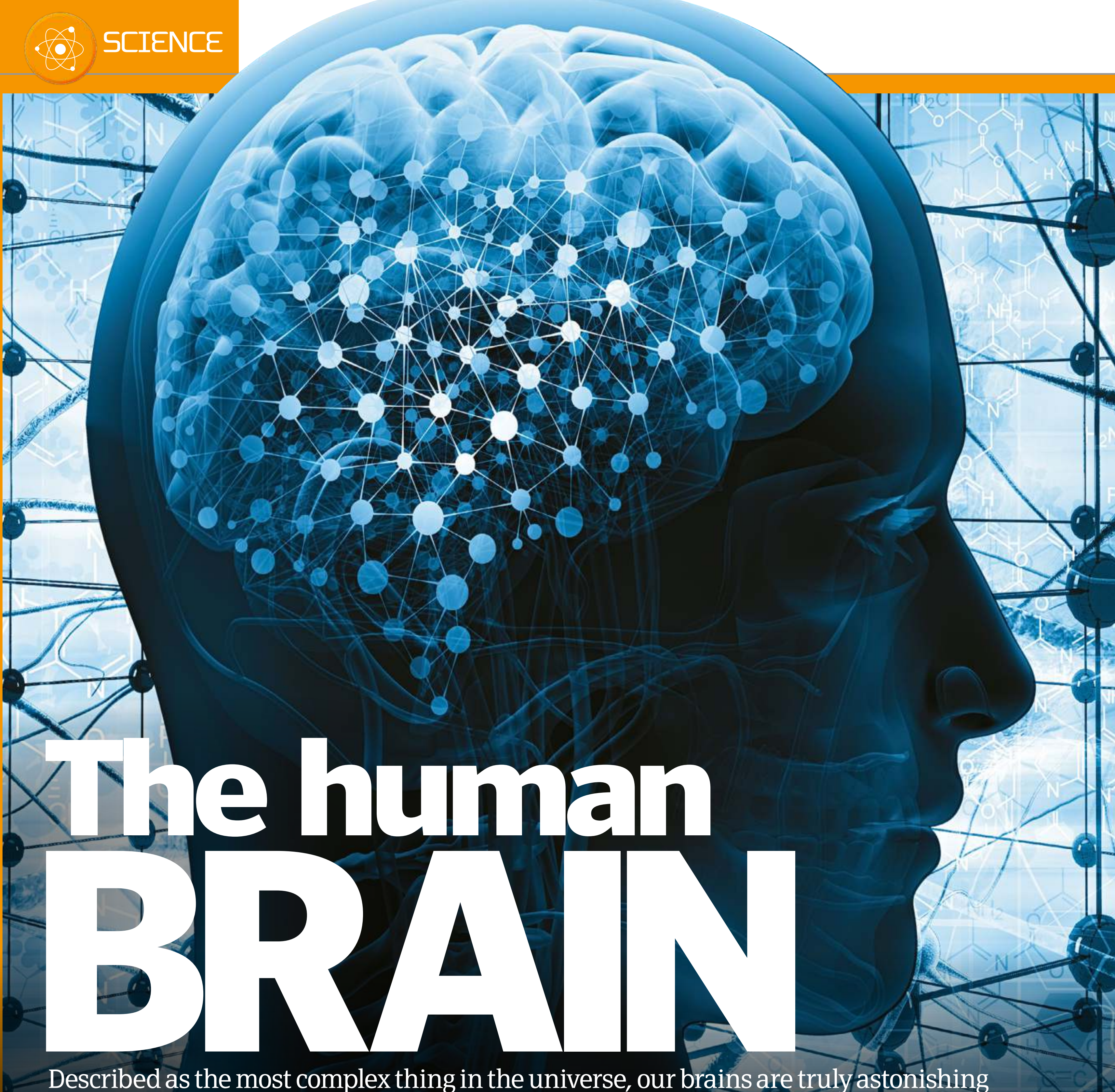
Next-generation health tech could use everyday objects to monitor your vital signs

Nutrition tracking

Nutrition trackers make calorie counting easy. Apps like MyFitnessPal pull nutritional information from a vast database at the scan of a barcode or the tap of a screen, breaking down calories, fat, protein, carbs, and even micronutrients like cholesterol, vitamins and sodium. But that's just the start. The latest apps are attempting to make food monitoring even easier by training AI to identify photographs of food. The food-logging app Lose It! has a beta mode called Snap It, which logs calories based on a simple picture of your meal.

Home help

Smart tech is entering our homes to take charge of the lights, heating, entertainment and internet, and healthy home upgrades are following close behind. Smart scales calculate body fat percentage by measuring a tiny current as it passes through the body. Room sensors measure air quality, temperature, humidity, and noise. And Google has filed patents for smart tech that can monitor blood pressure and heart rate through your toilet and bath mat. The same patent also mentioned a mirror capable of measuring skin colour variations and an ultrasonic bathtub.



The human BRAIN

Described as the most complex thing in the universe, our brains are truly astonishing

The brain makes up just two per cent of our total body weight, but crammed inside are approximately 86 billion neurons, surrounded by 180,000 kilometres of insulated fibres connected at 100 trillion synapses. It's a vast biological supercomputer.

The cells in the brain communicate using electrical signals. When a message is sent, thousands of microscopic channels open, allowing positively charged ions to flood across the membrane. Afterwards, more than 1 million miniature pumps in each cell move the ions back again ready for the next impulse.

The cell bodies of the neurons, and their connections, are contained within the grey matter, which consumes 94 per cent of the oxygen delivered to the brain. Different areas are responsible for different functions, and wiring them together is a fatty network of fibres called white matter.

When a signal reaches the end of a nerve cell, tiny packets of chemical signals spill out onto the surrounding neurons. These connections, called synapses, allow messages to be passed from one cell to the next. Each neuron can receive thousands of inputs, coordinating them in time and space, and by type of chemical, to decide what to do next.

Scientists have been electrically and chemically stimulating the brain to see how it responds to different signals, recording electrical activity to map thoughts and using imaging like functional MRI to track the blood flow increases that reveal when nerve cells are firing. The cells of the brain can also be studied inside the lab. Thanks to these investigations we know more about this incredible structure than ever before, but our understanding is only just beginning. There is so much more to learn.

Brain development

From a single cell to an incredibly intricate network in just nine months

16 Within weeks of fertilisation, neural progenitors start to form; these stem cells will go on to become all of the cells of the central nervous system. They organise into a neural tube when the embryo is barely the size of a pen tip, and then patterning begins, laying out the structural organisation of the brain and spinal cord. At its peak growth rate, the developing brain can generate 250,000 new neurons every minute. By the time a baby is born, the process still isn't complete. But, by the age of two, the brain is 80 per cent of its adult size.

Pyramidal neurons, like these, are found in the hippocampus, cortex and amygdala

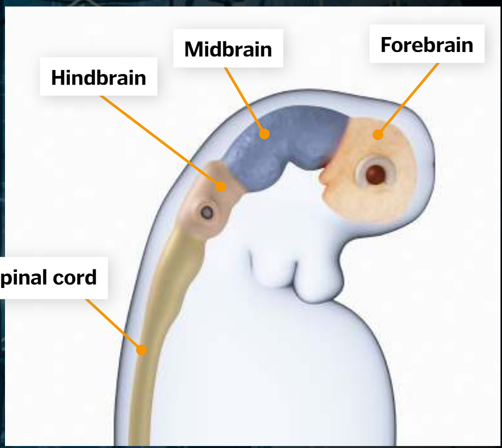
17

20 watts

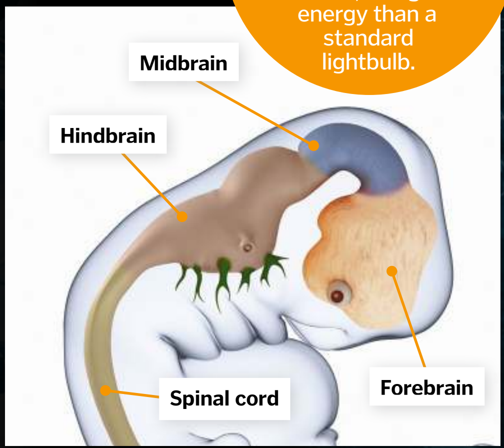
Your brain is incredibly efficient, using less energy than a standard lightbulb.

Brain formation

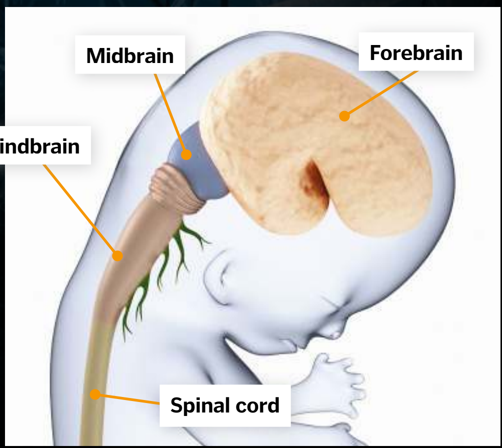
This astonishing structure is formed and refined as pregnancy progresses



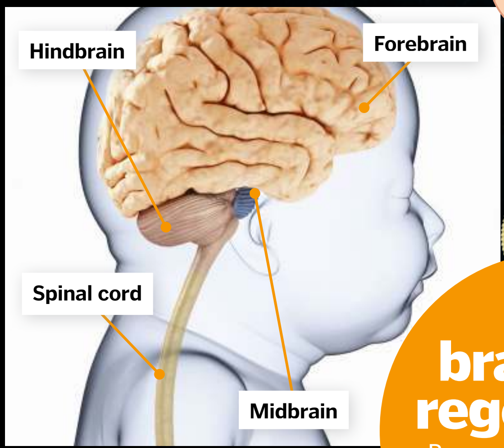
4 weeks
Brain development starts just three weeks after fertilisation. The first structure is the neural tube, which divides into regions that later become the forebrain, midbrain, hindbrain and spinal cord.



6 weeks
The pattern of the brain and spinal cord is now laid out and is gradually refined, controlled by gradients of signalling molecules that assign different areas for different functions.



11 weeks
As the embryo becomes larger, the brain continues to increase in size and neurons migrate and organise. The surface of the brain gradually begins to fold. At this point, a foetus only measures about five centimetres in length.



Birth
Before a baby is born, around half of the nerve cells in the brain are lost and connections are pruned, leaving only the most useful. This process continues after birth.

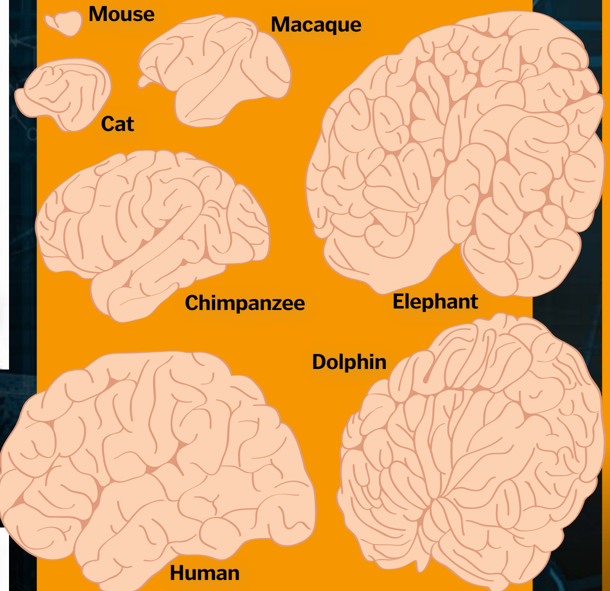
18

Why the brain is wrinkled

The brain folds in on itself to cram in more processing power

The folds and pockets of our brains are a biological rarity that we only share with a few other species, including dolphins, some primates and elephants. It's a clever evolutionary adaptation that allows intelligent species to squash a huge amount of cortical tissue into a small space, allowing enormous brainpower to be crammed into our relatively small skulls.

Folding starts during the second trimester of pregnancy, creating ridges (gyri) and fissures (sulci), but the biology behind the distinctive wrinkles is stranger than you might think. The organisation of the brain is determined by complex cascades of chemical signals, but the overall shape seems to be the result of simple physics. Grey matter sits on the outside of the brain and, during development, its growth rapidly outpaces the growth of white matter underneath. This puts mechanical stress on the structure, forcing the outside to buckle and curl.



More wrinkled brains are associated with higher intelligence (brain sizes not to scale)

19

The brain can regenerate

Research has shown that certain areas of the adult brain can continue to produce new neurons, a process known as neurogenesis.

"Our brains contain 86 billion neurons and 180,000 kilometres of fibres"

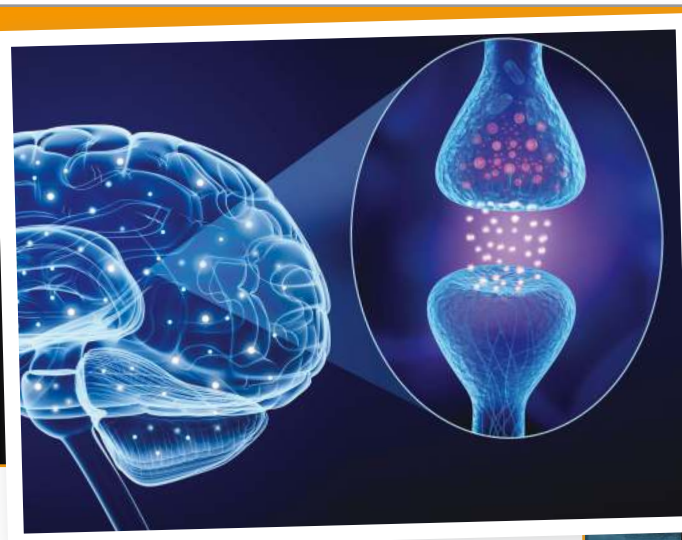
Making memories

The brain can store around 1 million gigabytes of data

20 A team at the Salk Institute in California estimate that the brain can store around 1 petabyte of information, stuffed into the connections between nerve cells. That's around 2,000 years worth of MP3 music or 223,000 DVDs. And, incredibly, it's possible to watch memories being made.

The Weizmann Institute in Israel and UCLA in the US captured memory formation in action. Patients watched clips of videos and were then asked to recall what they'd seen. The neurons that lit up when they watched the first time lit up again as they relived the experience inside their heads – a bit like an echo.

Recent research from the US and Japan suggests that these echoes are actually stored twice – once in the hippocampus and again in the cortex. The hippocampus handles short-term storage and gradually forgets, but as it does so it helps to reinforce the memory in the cortex, allowing long-term recall.



Neurons make new connections when a memory is formed

21

Self-cleaning brains

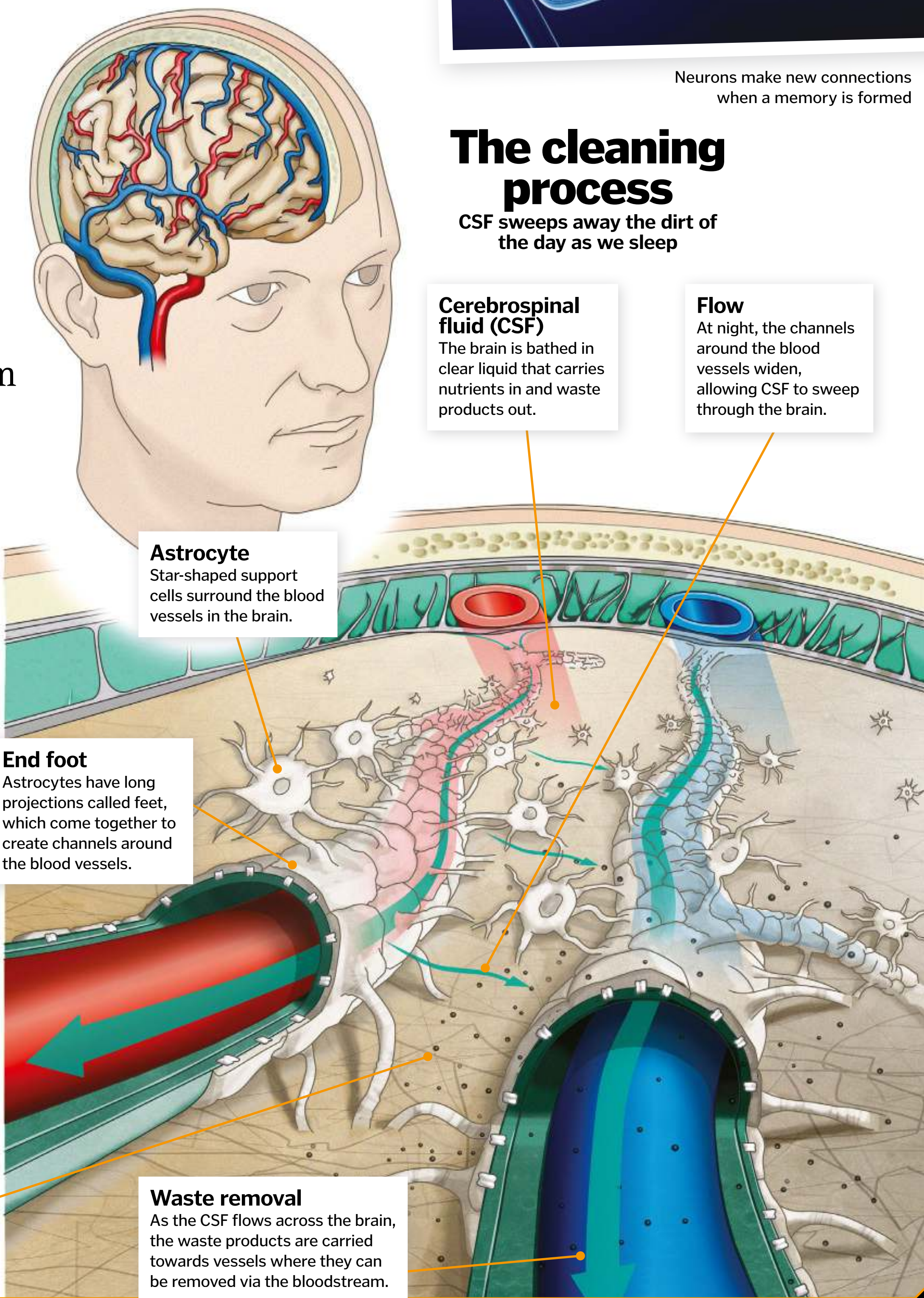
We have a built-in system to clear toxic waste from between our brain cells

Sleep is one of the brain's great mysteries, but research on mice has revealed an intriguing night time cleanup system. The brain is shielded by a barrier made and maintained by cells called astrocytes. They hug the blood vessels, controlling what's allowed in and out, and a space between the vessel wall and these cells seems to play a crucial role in keeping the brain clean.

At night, the astrocytes relax their grip and the space fills up with a clear liquid called cerebrospinal fluid (CSF). It's pushed along by the movement of the blood vessels underneath, swishing up through the astrocytes and out into the spaces between brain cells. As it passes, it picks up waste and debris, carrying the particles back towards the bloodstream so that they can be removed from the brain.

The cleaning process

CSF sweeps away the dirt of the day as we sleep



22

Electrodes can detect the electrical signals produced by our brains

Mind reading

Thoughts are electricity, and that means that they can be detected and decoded

Electrodes placed on the scalp can listen out for signals made by the buzzing of neurons inside the brain, and researchers are developing ways to decode the messages. It works by using a computer that can learn the patterns that the brain creates when people focus on a single, simple thought, like a movement or a word. The signals can then be used to control a prosthetic, command a computer, or they can even be sent to someone else's brain using magnets placed across their scalp.

It might sound like science fiction, but this field is moving so quickly that even big companies like Facebook want in on the action. In 2017, Mark Zuckerberg announced that the company are "working on a system that will let you type straight from your brain about five-times faster than you can type on your phone". They're also working on a skin sensor that can translate touch into thoughts, mimicking what the ear does with sound.

MRI scanners reveal the inner workings of the brain

Mind over matter

Sheer brainpower drives the healing impact of the placebo effect

23

Placebos are an important part of testing new treatments. Before new medicines or procedures hit the clinic, they are compared to a pill, patch or injection that doesn't contain any active ingredients. Neither the doctor nor the patient know which is which, helping to prevent bias. But the brain is a powerful thing, and just thinking you're getting treatment can make you feel better – or give you side-effects.

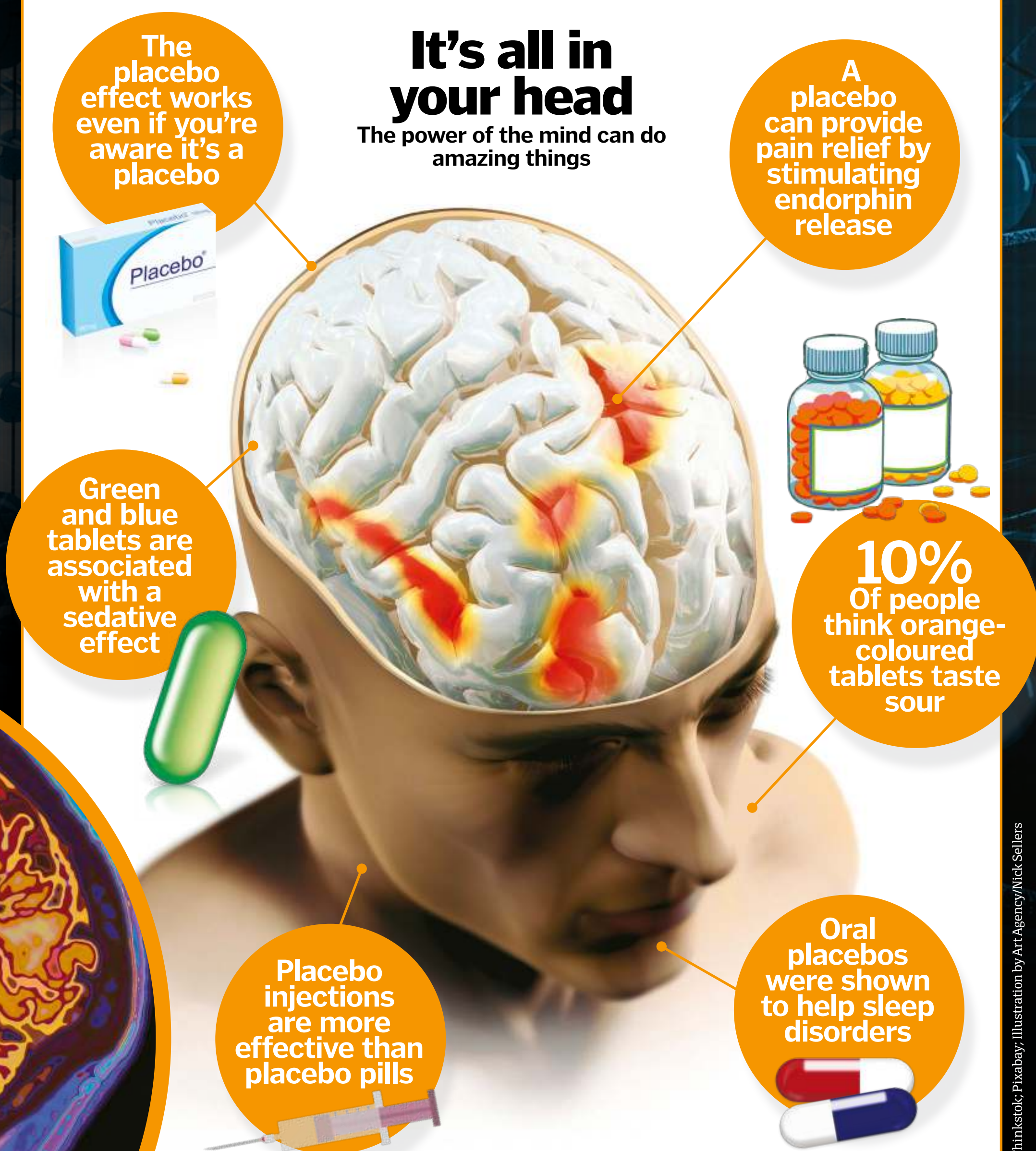
One of the most famous studies, led by Jon Levine in 1978, attempted to find out what was happening. He and his team gave placebo 'painkillers' to patients after wisdom tooth extraction. Their studies revealed that the pain relief the patients experienced was actually down to the release of their own natural painkillers – endorphins.

This strange effect can't cure cancer or get rid of asthma, but, with a little help from sugar pills and saline injections, your brain can change the way you feel.

> *"Just thinking you're getting treatment can actually make you feel better"*

It's all in your head

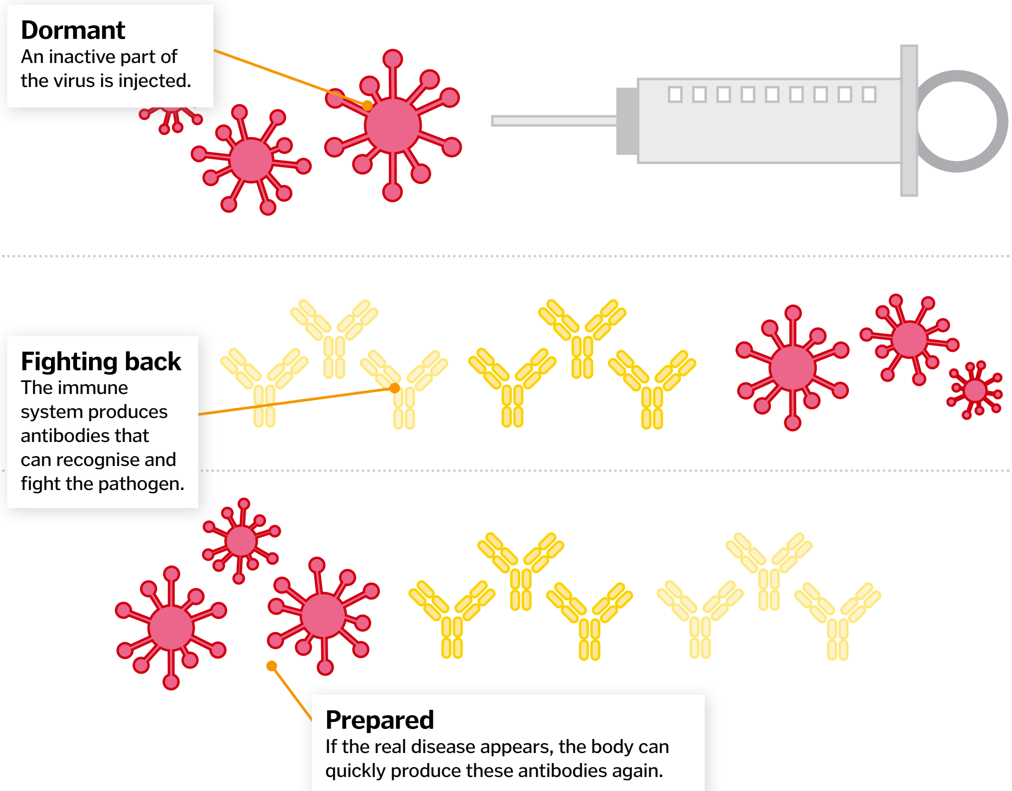
The power of the mind can do amazing things



Vaccines

How we can encourage the body to prepare an army of antibodies to fight disease

24 When foreign bacteria, viruses or other pathogens enter the body, the immune system responds by producing molecules called antibodies, which recognise and bind to the foreign cells. A vaccine contains a weakened, dead or inactive part of a pathogen, which triggers the immune system to produce antibodies without causing illness. The harmless invaders are eliminated, but some antibodies remain. Should the real disease ever appear, the antibodies will be ready to destroy it.



DNA

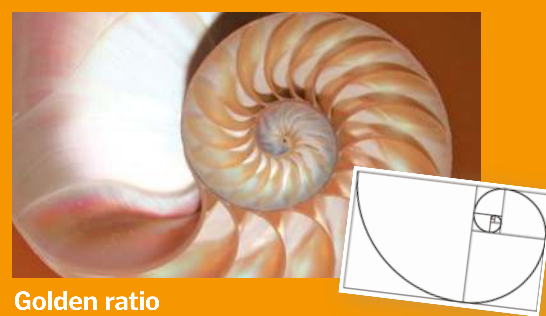
The incredible instruction manual packaged inside our cells

25 DNA is a complex molecule made up of chains of four different building blocks called nucleotides. The sequence of nucleotides acts like a code, instructing the cell to make certain proteins at certain times, driving biological processes in the body. DNA is found inside most cells and is passed from parents to their children. Variations in the sequence result in different characteristics, such as eye colour or blood group, and can also lead to genetic disorders such as cystic fibrosis. Advances in our understanding of DNA could mean that in the future, genetic disorders will be treated with 'personalised' medicine that has been tailor-made for your DNA.

Hidden maths

26 How numbers, patterns and ratios shape nature

Fibonacci Sequence
In the Fibonacci Sequence, each number is the sum of the previous two: 1, 1, 2, 3, 5, 8, 13, 21 and so on. Many flowers have a Fibonacci number of petals, and seed heads are often arranged in intricate Fibonacci spirals.



Golden ratio
The ratio between subsequent numbers in the Fibonacci Sequence (close to 1.618) is known as the 'golden ratio'. This ratio is frequently found in complex patterns in nature, such as the spiral of a snail's shell.

Fractals
These never-ending patterns are created by repeating the same process. An example is the 'dome' of a Romanesco broccoli, which is divided into smaller, identical domes, themselves divided again, and so on.

Symmetry
Butterfly wings are bilaterally symmetrical, while a starfish is an example of radial symmetry. Nature's examples of symmetry range from the arrangement of a snowflake to the vast structure of the Milky Way.

Stem cells

The cells that are full of potential and replenish the body's specialised tissues

27 Stem cells are the source of every tissue and organ in the body. Inside an embryo a cluster of stem cells continuously divides. With each division the resulting cells develop different characteristics that mean they can perform specialised functions, a process known as differentiation. Eventually, these cells will go on to form skin, muscle, bone and every other part of the body. Stem cells can also divide to produce identical copies of themselves, so the body's supply of stem cells never runs out. This property is known as 'self-renewal'.

Even a fully grown organism needs a constant supply of new cells to grow, repair damage or just keep functioning as normal. Many types of cells with specialised functions – such as red blood cells, neurons or skeletal muscle fibres – are unable to divide and replace themselves. Instead, the body has a reservoir of stem cells ready to divide and develop into the cell type that is required.The two key abilities of stem cells – differentiation and self-renewal – mean they could be incredibly useful for studying and treating disease.

In the past, stem cell research has been seen as controversial due to the use of embryonic stem cells, usually taken from embryos left over from fertility treatment. However, more recently, scientists have developed new ways of growing stem cells in the lab, opening up the possibility of exciting new treatments, from building bones to replacing damaged neurons.

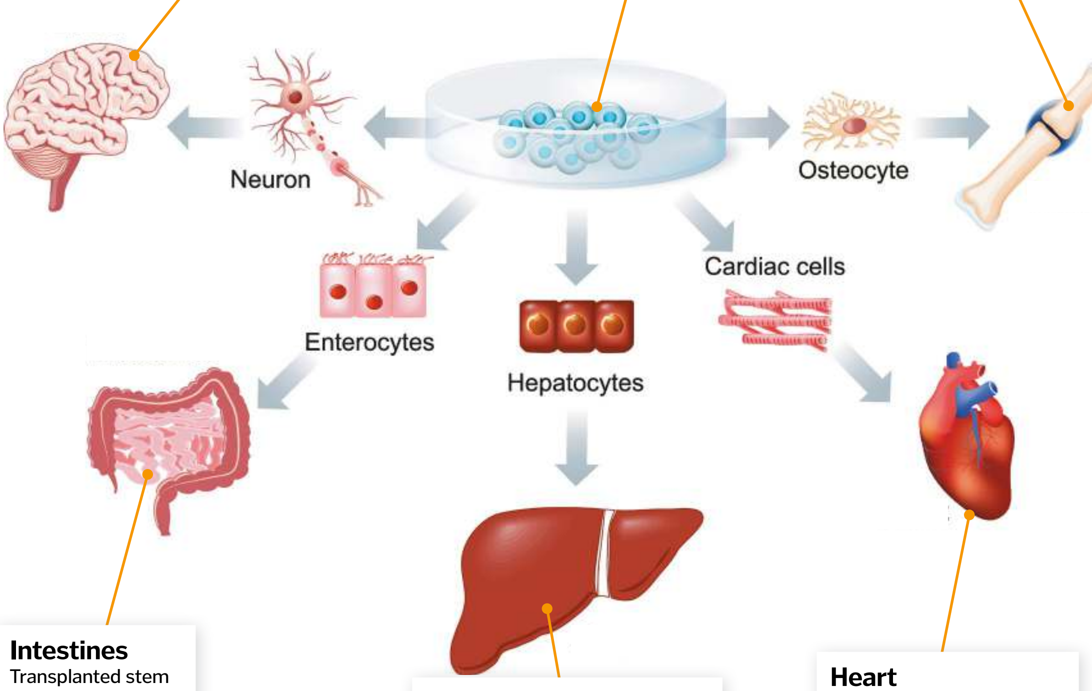
What could stem cells do?

How these remarkable cells could revolutionise medicine

Brain
New, healthy neurons grown from stem cells could be used to replace those lost due to neurodegenerative diseases such as Alzheimer's.

Stem cells
The cells in a patient's skin sample could potentially be reprogrammed into a personalised supply of stem cells.

Bone
Damaged bone or cartilage could be treated with stem cells in order to help the tissue regrow, while avoiding invasive surgery.



Intestines
Transplanted stem cells could help repair damaged intestinal tissue to treat inflammatory bowel disease.

Liver
New liver cells, or hepatocytes, could be made for patients with chronic liver disease, avoiding the need for a transplant.

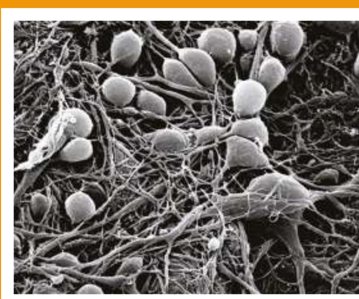
Heart
Healthy cardiac muscle cells could be grown inside the lab and transplanted into patients with chronic heart disease.

"A reservoir of stem cells is ready to divide and develop into any cell type"

Making stem cells in the lab

The only natural pluripotent stem cells are those found in embryos. However, in 2006, Japanese scientist Shinya Yamanaka found a way to 'reprogramme' specialised cells found in adults, transforming them into stem cells. Starting with skin cells, Yamanaka was able to reverse the cell differentiation by adding four key genes. The resulting cells were named induced pluripotent stem cells, or iPSCs.

Already, the use of iPSCs in research has enhanced our understanding of genetic conditions including Parkinson's, muscular dystrophy and Down's syndrome. Although there are still technical hurdles to overcome, iPSCs offer the potential to treat many genetic and degenerative diseases by replacing damaged cells with healthy new ones.



Types of stem cell

Totipotent
Found in: Zygotes
Able to develop into an entire organism, plus the embryonic tissues.

Pluripotent
Found in: Embryos
Able to develop into any of the cell types inside the adult body.

Multipotent
Found in: Tissues, organs and bone marrow
Produce the cell types found in one kind of organ or tissue.

The Large Hadron Collider

The huge machine helping scientists to uncover the structure of the universe

28

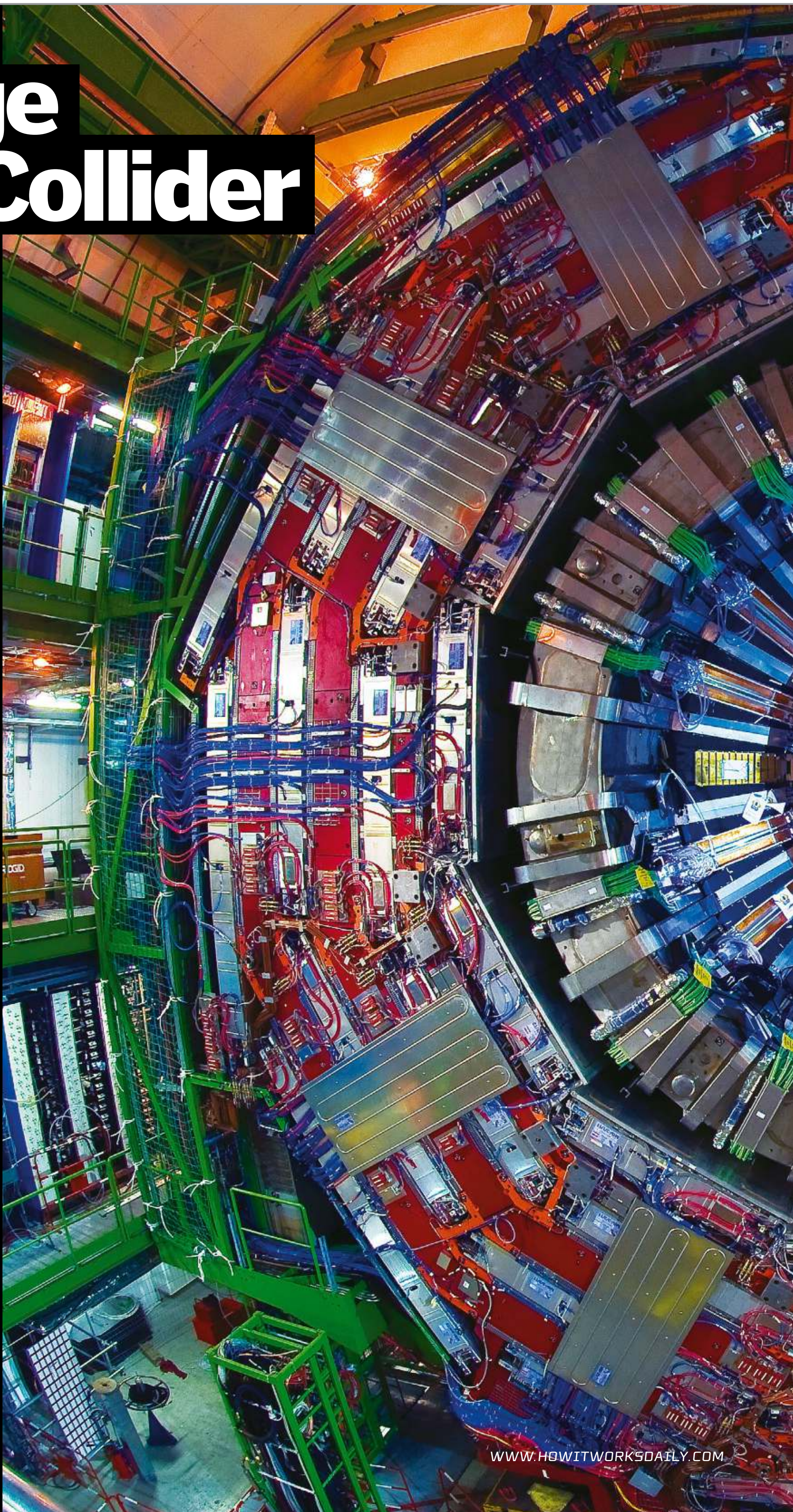
The Large Hadron Collider, or LHC, is a physics experiment on a phenomenal scale. The 27-kilometre tunnel is the world's largest particle accelerator, a powerful machine that could help us to understand the fundamental laws of nature. But although the setting is huge, the science is very small indeed; the LHC provides a peek inside the nucleus of an atom, which is made up of particles that are less than a trillionth of a millimetre across.

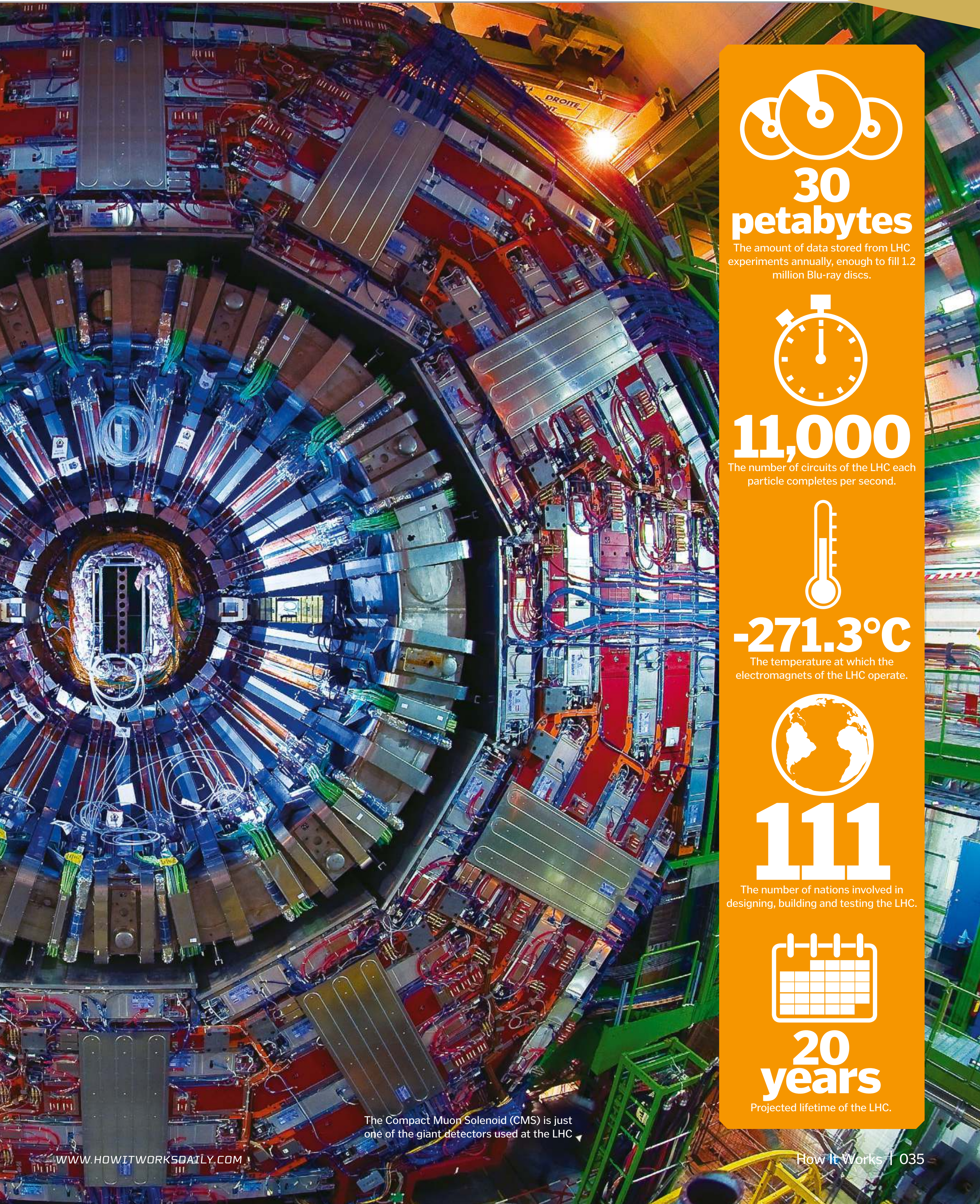
Inside the LHC, these subatomic particles, or protons, are fired at each other at high speed using electromagnets, producing millions of proton collisions per second. These are captured by sensitive detectors and give scientists an insight into the conditions that existed in the fraction of a second after the Big Bang.

The LHC is one of several particle accelerators belonging to the European Organization for Nuclear Research, or CERN. The accelerators are used in succession to boost the speed of the protons until they reach almost the speed of light. Many different projects are based at the accelerator complex at CERN, including the ATLAS and CMS experiments that resulted in the Higgs boson being identified in 2012.

The LHC first powered up in 2008, but the construction work didn't stop there. The collider gets switched off for a while each year so that essential repairs and upgrades can take place. In 2017, one of the LHC's detectors, the Compact Muon Solenoid, or CMS, underwent a complex upgrade on its pixel detector, which will allow it to capture particle collisions in even finer detail.

Scientists conducting a 'heart transplant' to replace the pixel detector at the core of the CMS detector in March 2017





The Compact Muon Solenoid (CMS) is just one of the giant detectors used at the LHC

30 petabytes

The amount of data stored from LHC experiments annually, enough to fill 1.2 million Blu-ray discs.

11,000

The number of circuits of the LHC each particle completes per second.

-271.3°C

The temperature at which the electromagnets of the LHC operate.

111

The number of nations involved in designing, building and testing the LHC.

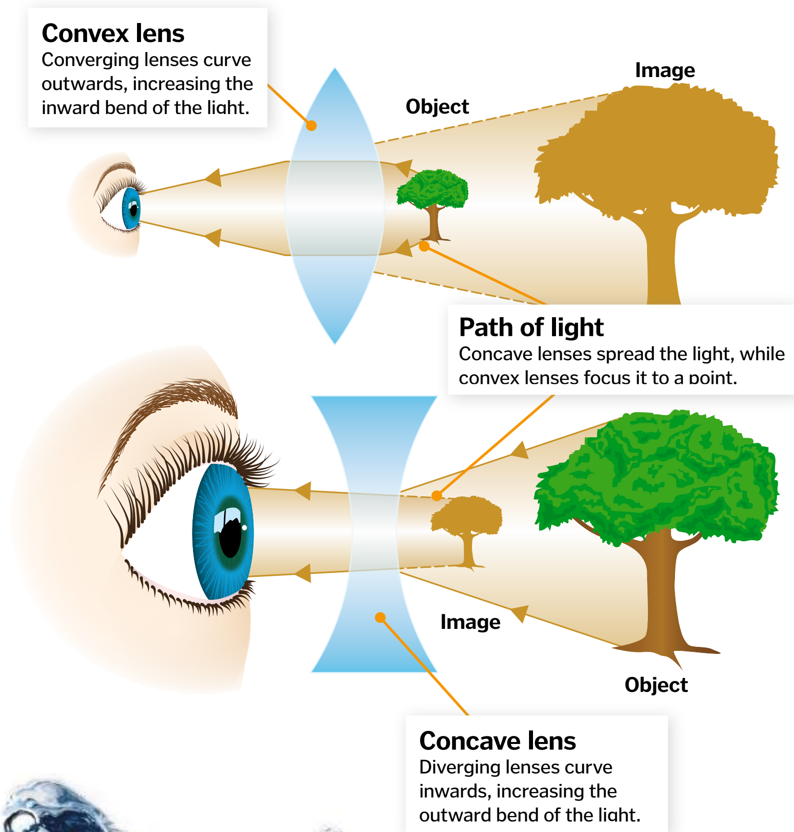
20 years

Projected lifetime of the LHC.

Lenses

Bending light allows us to study the smallest cells and the furthest galaxies

29 Light bends as it passes through materials of different densities. As it enters a more dense material, it is deflected towards the 'normal', an imaginary line at 90 degrees to the surface, but as it moves into a less dense material it bends away. This is the basis of lenses. Adding a curve changes the direction of the normal, altering the amount that the light is bent and allowing tiny objects to be magnified or distant images to be enlarged.



Mendeleev's periodic table

A Russian chemist cracked the chemical code and predicted unknown properties

30 In 1860, just 60 elements had been found, and no one knew how they should be organised. Dmitri Mendeleev lined the elements up by atomic mass and noticed that similar properties kept reappearing in the same sequence. A soft, very reactive metal would be followed by a shiny, less reactive metal. And several elements later, a highly reactive, salt-producing non-metal would appear. He arranged the elements into rows called 'periods', with similar elements stacked below each other in columns called 'groups'. When elements appeared in the wrong order he swapped them around. If no element fitted into a column or row, he left a gap and made a prediction.

Group → / ↓ Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
Lanthanides			57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
Actinides			89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

1. Atomic number The elements line up in order of atomic number (the number of protons in the nucleus of each atom).

2. Period After a set interval, the properties of the elements start to repeat. At this point they are arranged on a new row below.

3. Group Elements in each column share similar properties. The first are the alkali metals, which are all highly reactive.

4. Predictions Mendeleev correctly predicted the weight, density, melting point and valency of three elements, including the metal gallium.

31

Water

The weird chemistry of water is essential for life as we know it

Ice floats
When water freezes, the molecules move apart, reducing its density. This stops rivers and lakes freezing solid.

It should be a gas
Water molecules are smaller than carbon dioxide, but they hold together as a liquid thanks to hydrogen bonds.

It resists temperature change
It takes 4.2 joules of energy per gram to raise water temperature by 1 degree Celsius, preventing the oceans from evaporating.

It's the universal solvent
Polar molecules (with partial positive and negative charges) dissolve in water, enabling the chemistry of life.

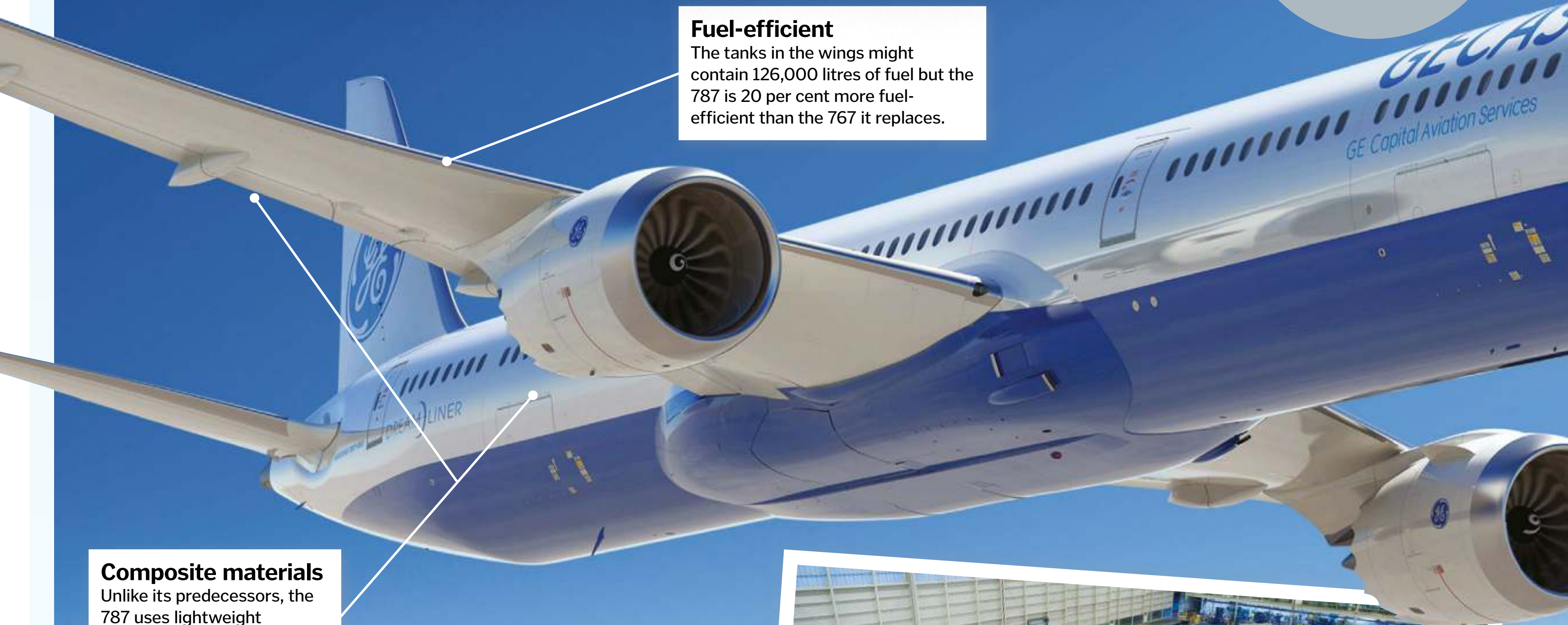
It's sticky
Water molecules cling to each other and to surfaces, creating surface tension and capillary action.

FLIGHT

In making the most distant and exotic locations ever more accessible, air travel continues to change the world

33

IT'S THE SAFEST WAY TO TRAVEL
There are just 0.07 fatalities per billion passenger miles travelled by air. For motorcycles, the figure is 213.



Commercial airliners

The passenger planes that enable us to cross oceans and continents with ease

32 Until the 1950s, the state-of-the-art in inter-continental travel was the ocean-going passenger liner, but it wasn't exactly fast. Atlantic crossing times might have improved from two weeks in 1838 to 3.5 days by 1952, but passages to Australia never took much less than a month. All this changed with the introduction of airliners and, in particular, the jet airliner. The world's first commercial jet liner, the de Havilland Comet, was built in Hertfordshire, England, and entered passenger service in 1952. It reduced the journey time from London to Johannesburg to under 24 hours.

Over 60 years of development of commercial airliners has brought us higher speeds, longer ranges, greater capacities and improvements in efficiency. From just 36 passengers in 1952, the twin-decked Airbus A380 can now accommodate up to 853 passengers, and from a maximum range of 5,350 kilometres at the dawn of jet passenger travel, today's record holder is the Boeing 777-200LR, which can fly 21,601 kilometres without refuelling.

Jet engines

More reliable and powerful than propellers, jet engines enable planes to travel faster and further

34

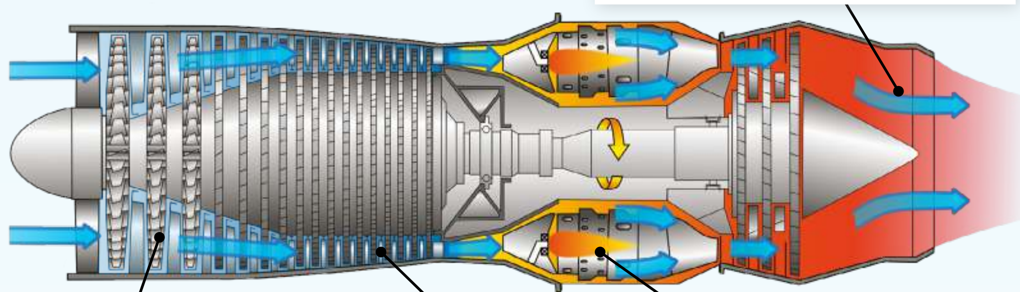
They might cost tens of millions of pounds, and they might contain tens of thousands of parts but, at a fundamental level, the operation of a jet engine is easy enough to get your head around. According to jet engine manufacturer Rolls Royce, four steps – suck, squeeze, bang and blow – are all that's needed to get you airborne.

General Electric's GE90 is the most powerful jet engine in the world, capable of producing 568,927 Newtons of thrust

The total number of parts used in the 787 cockpit has been reduced for a cleaner look

Inside the jet engine

The secrets behind the wonder of flight that powers most commercial airliners



Blow
Exhaust gasses and air are blown out of the engine to propel the aircraft forwards. The escaping gasses power a turbine that is used to turn the earlier fan blades and compressor.

Suck
Rotating fan blades suck air into the engine; more than a ton per second in the largest engines.

Squeeze
The air is squeezed by a multi-stage compressor to a fraction of its original volume and, in so doing, heats it up.

Bang
Super hot air is mixed with fuel and ignited to generate exhaust gasses at thousands of degrees.

Boeing 787 Dreamliner

What makes the 787 more efficient and quieter than its predecessors?

Quieter engines
The exhaust duct cover has a chevron pattern to improve mixing of exhaust and air, making the 787 significantly quieter inside and out.

All nine of Boeing's commercial airliners lined up in order from the 1957 707 (front) to the latest 787 (rear)

VTOL technology

Powerful engines can allow jets to take off without a runway

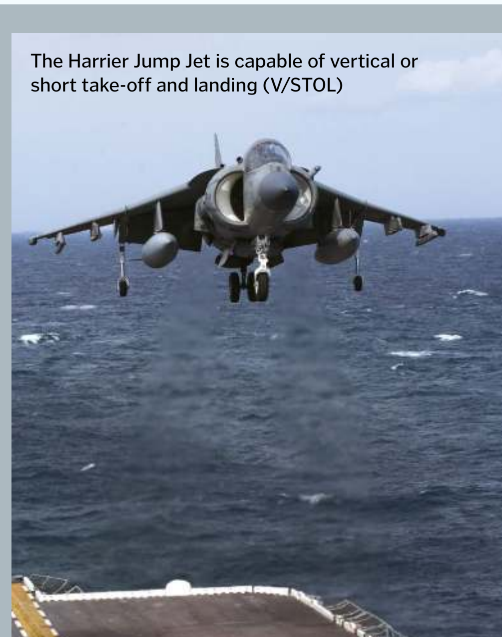
35

Helicopters take off and land vertically, so they're not reliant on airports, but fixed wing aircraft offer increased speed and range. VTOL aircraft – vertical take-off and landing – offer the best of both worlds. These fixed-wing aircraft are mostly operated by the military and there are two main types in operation today.

The Harrier Jump Jet is a single-engine jet fighter, but the thrust from that engine is directed through four nozzles. The nozzles point downwards for take-off and landing but rotate into a horizontal position for forward flight.

The V-22 Osprey, on the other hand, has a turbo-prop engine on each wing. For take-off and landing these are angled vertically, making the aircraft a twin rotor helicopter. For normal operation these are angled horizontally, just like any other propeller-driven aircraft.

The Harrier Jump Jet is capable of vertical or short take-off and landing (V/STOL)



The HondaJet

The luxury private plane improving efficiency with its innovative design

36 The HondaJet has two engines and seats four passengers and, in that respect, is similar to several other small executive jets. Here the similarity ends, though, because unlike nearly all other jet aircraft, those two engines are mounted on pylons above the wings.

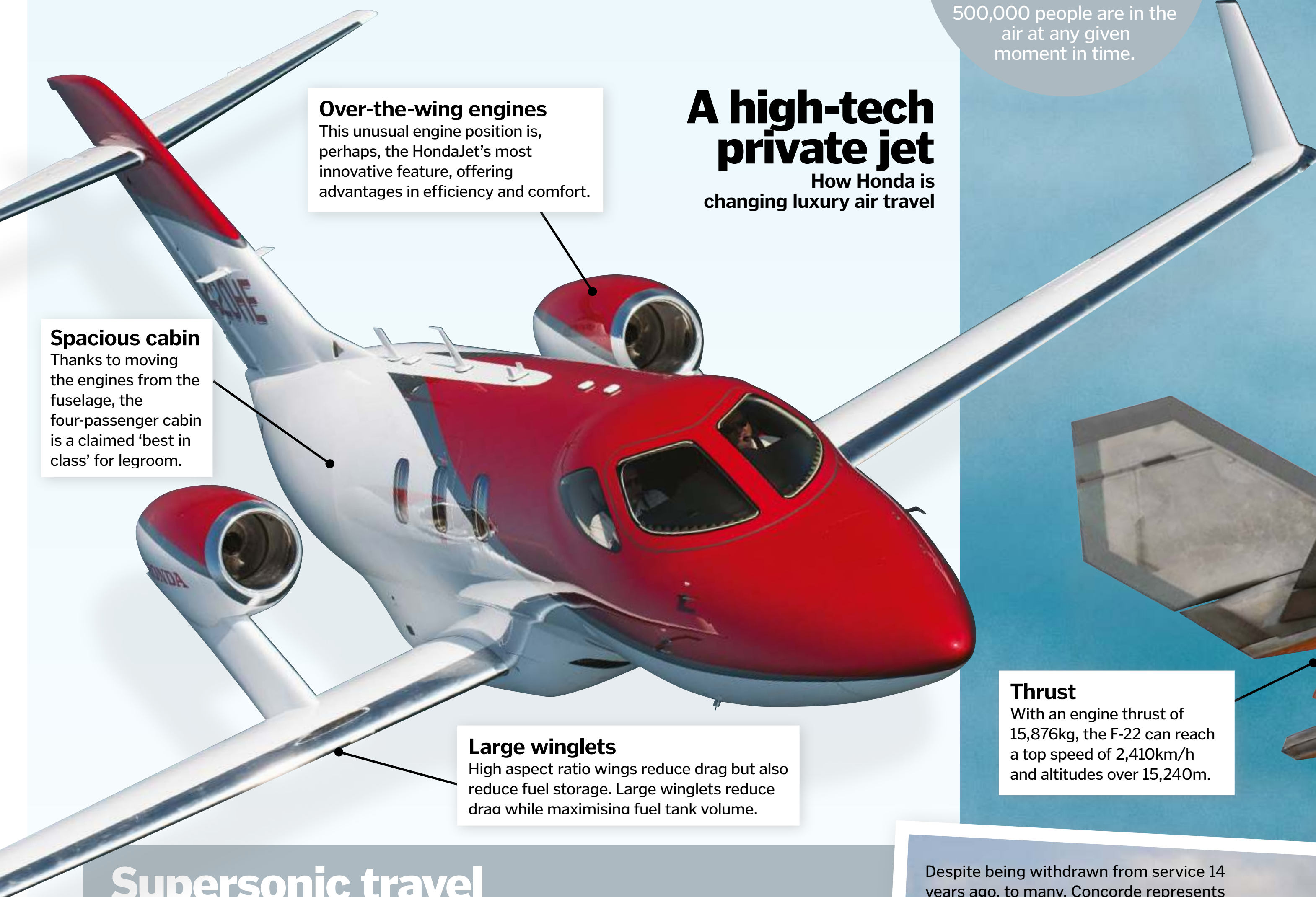
Commonly, business jets have fuselage-mounted engines because mounting them under the wing – as they are on larger jet aircraft – would place them too close to the ground. But Honda has broken the mould and shown that an above-the-wing design offers several advantages. First, by removing the engine mountings from the fuselage, cabin space is increased. Second, it allows a natural laminar flow, thereby reducing drag. This leads to improved efficiency and a quieter cabin.

38 AIRBORNE POPULATION

It's been estimated that over 500,000 people are in the air at any given moment in time.

A high-tech private jet

How Honda is changing luxury air travel



Supersonic travel

Breaking the sound barrier to dramatically reduce journey times

37 Concorde made history in 1977 by cutting the flight time between London and New York from eight hours to 3.5. It flew at more than twice the speed of sound, with a cruising speed of almost 2,200 kilometres per hour. This was achieved using four specially developed Rolls Royce Olympus engines, but it was also necessary for the aircraft to fly at an altitude of 17,000 metres to achieve the benefits of lower air resistance. The characteristic delta wing was also key.

Concorde was one of only two supersonic airliners, the other being the Soviet Tupolev Tu-144, and both are now grounded. The failure of Concorde is generally attributed to it being noisy, polluting and expensive – the first four aircraft cost £1.13 billion ($1.45 billion) to build. But could today's technology make a success of supersonic flight? US-based company Boom Technology certainly thinks so. Its planned XB-1 will carry 55 passengers to anywhere in the world within 12 hours for the cost of an ordinary business class ticket.


Despite being withdrawn from service 14 years ago, to many, Concorde represents the pinnacle of air travel

Advanced fighter jets

The military aircraft pushing aeronautic technology to new heights

39

Some of the most technically advanced aircraft flying today are jet fighters and, if history repeats itself, sooner or later, many of the associated technologies will impact civilian aircraft. Today's latest and greatest, such as the Lockheed Martin F-22 Raptor, are referred to as fifth-generation fighters and boast some impressive features.

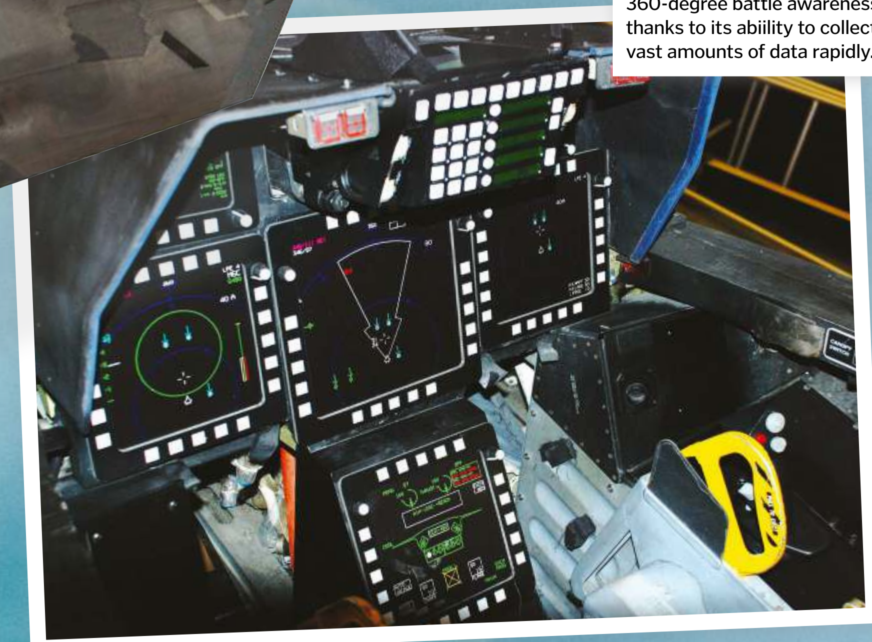
The F-22 can cruise at supersonic speeds over long ranges, while controllable nozzles, combined with a triplex fly-by-wire control system, make it exceptionally manoeuvrable. Its Pratt and Whitney F119 engines are pretty impressive, too, providing 22 per cent more thrust with 40 per cent fewer parts than fourth-generation engines. And as a stealth fighter, the F-22 is virtually invisible to radar.

The Lockheed Martin F-22 Raptor is arguably the most advanced fighter aircraft flying today

Built for stealth
Curves on the body of the jet scatter radar signals in various directions as opposed to back to the source.

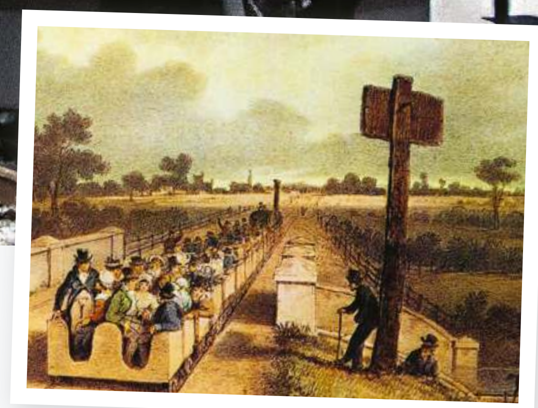
Battle ready
The F-22 provides a pilot with 360-degree battle awareness thanks to its ability to collect vast amounts of data rapidly.

Wingspan
With a wingspan of 13.56m and a wing area of 78.04m², the F-22 is capable of incredibly tight manouvres.



"Advancements in fighter jets can later impact civilian aircraft"

Steamboats were an asset to American industry, which had to move cargo over great distances



The Liverpool and Manchester Railway made moving freight between the cities a much quicker process

Steam power

Steam may not have started the Industrial Revolution, but it did drive manufacturing and transport into the modern age

Early steam engines were primarily used to pump water out of tin and coal mines, but they often broke down or exploded. It wasn't until the second half of the 18th century that James Watt introduced design improvements that would make steam engines viable power sources for factories manufacturing textiles and other goods. Thereafter, production wasn't dependent on moving water to drive machinery and could be centralised in areas where a large workforce was available.

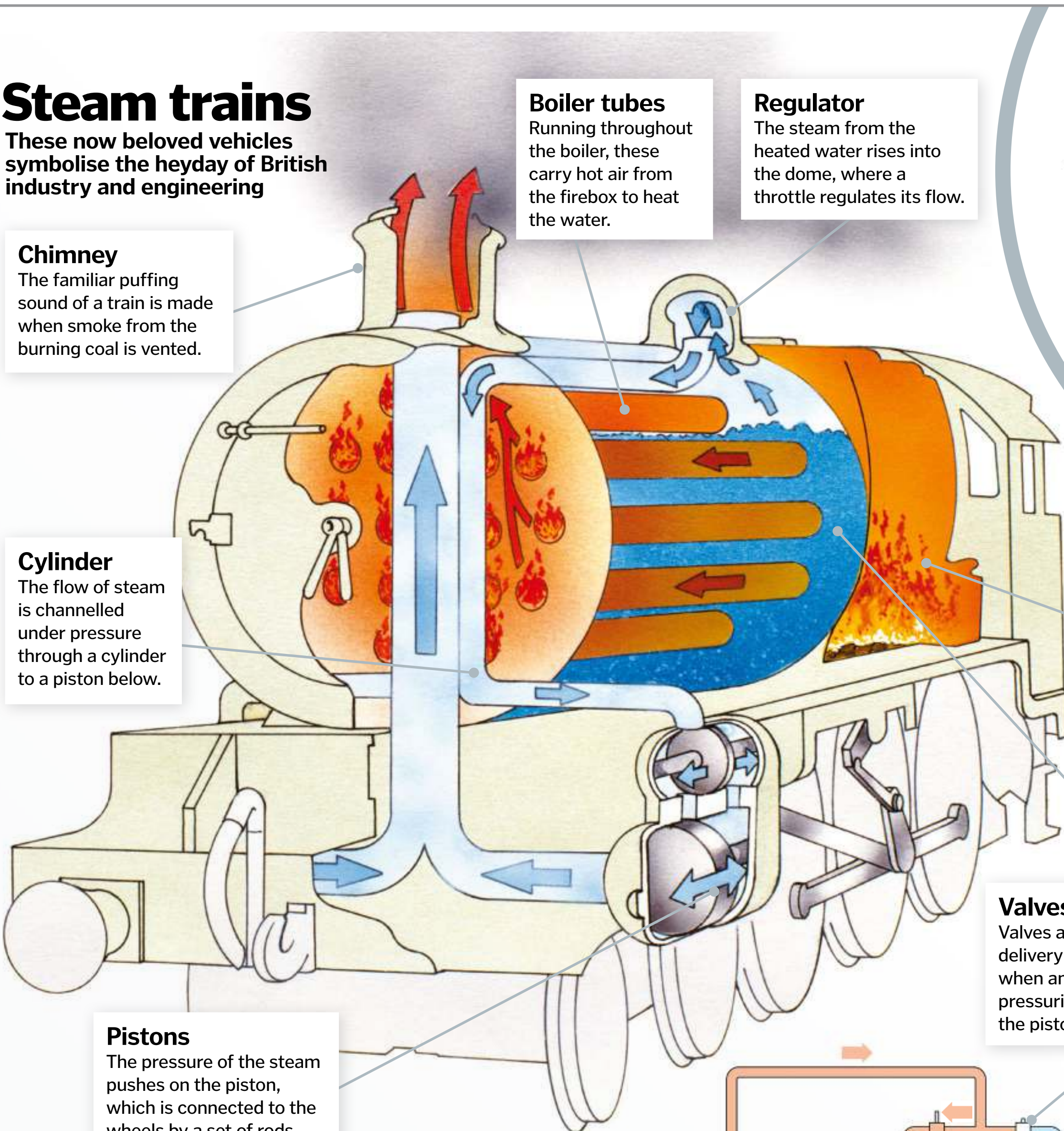
Complementing this shift was the development of steam-driven transport. In 1804, a steam engine designed by Richard Trevithick started carrying freight and workers along rails at a Welsh ironworks. It was George Stephenson's locomotive, however, that showed the world that steam was better for hauling heavy cargo than horses. That train took its first combined load of coal, flour and passengers along the new Stockton and Darlington Railway in 1825. Subsequent expansion of the rail network stimulated the further growth of Britain's industrial towns; trains could supply raw materials and distribute finished products quickly enough to satisfy demands for mass production from a growing population.

"The expansion of the rail network stimulated the growth of Britain's industrial towns"

Across the Atlantic, meanwhile, American manufactured goods were moving up the country's rivers on steamboats built on designs pioneered in the early 1800s by Robert Fulton. Yet what really put the new industrial nations on the world map was the advent of transatlantic shipping. Ships such as Isambard Kingdom Brunel's SS Great Western, which took its maiden voyage from Bristol to New York in 1838, showed that steam could get people and products far beyond the countries in which they originated much quicker than sails. Ship building boomed, and the stage was set for the globalisation of trade.

Steam trains

These now beloved vehicles symbolise the heyday of British industry and engineering



Chimney
The familiar puffing sound of a train is made when smoke from the burning coal is vented.

Boiler tubes
Running throughout the boiler, these carry hot air from the firebox to heat the water.

Regulator
The steam from the heated water rises into the dome, where a throttle regulates its flow.

Cylinder
The flow of steam is channelled under pressure through a cylinder to a piston below.

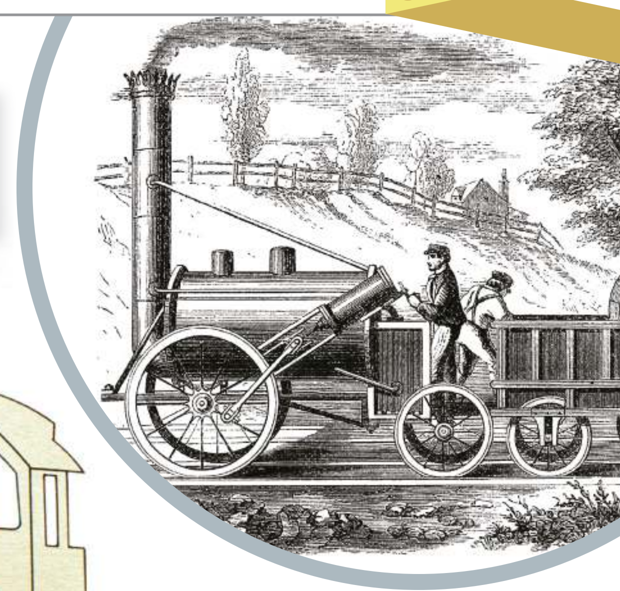
Firebox
Located within the cabin, this contains the burning coal that heats the water in the boiler.

Boiler
Like a giant kettle, the boiler contains water that is heated until it turns to steam.

Valves
Valves along the steam delivery pipes regulate when and how much pressurised steam enters the piston chamber.

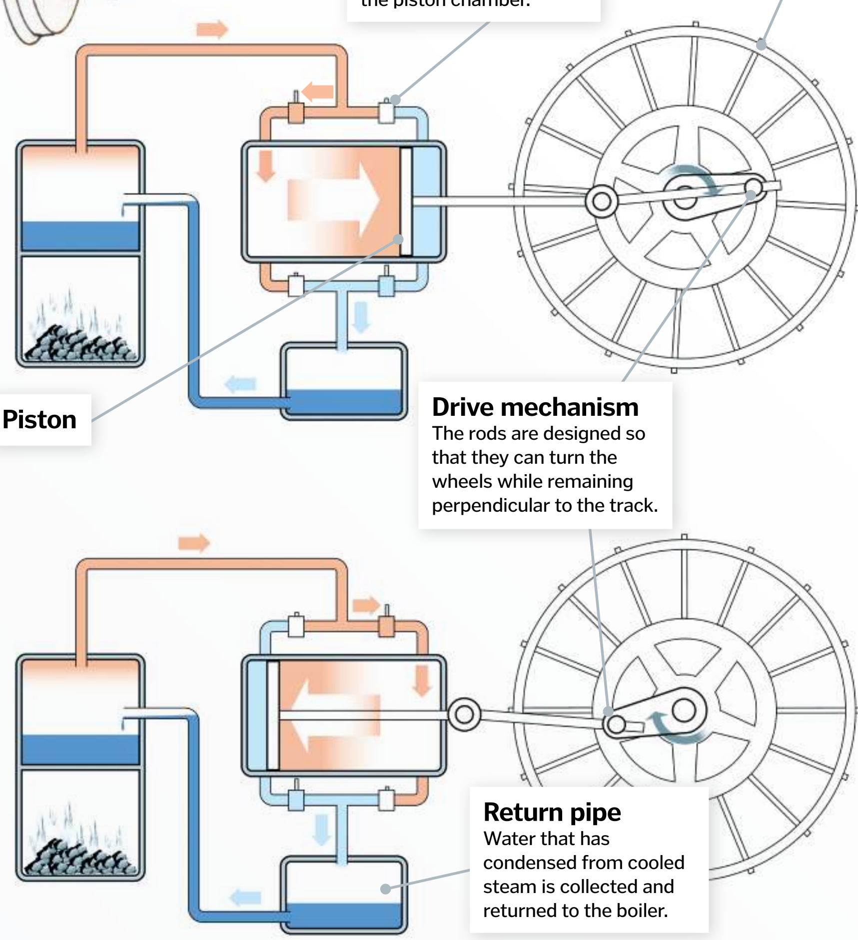
Wheels
The piston pushes the rod, which forces the wheels to turn.

Pistons
The pressure of the steam pushes on the piston, which is connected to the wheels by a set of rods.



Aptly named for the time, Stephenson's Rocket was able to travel at around 48km/h

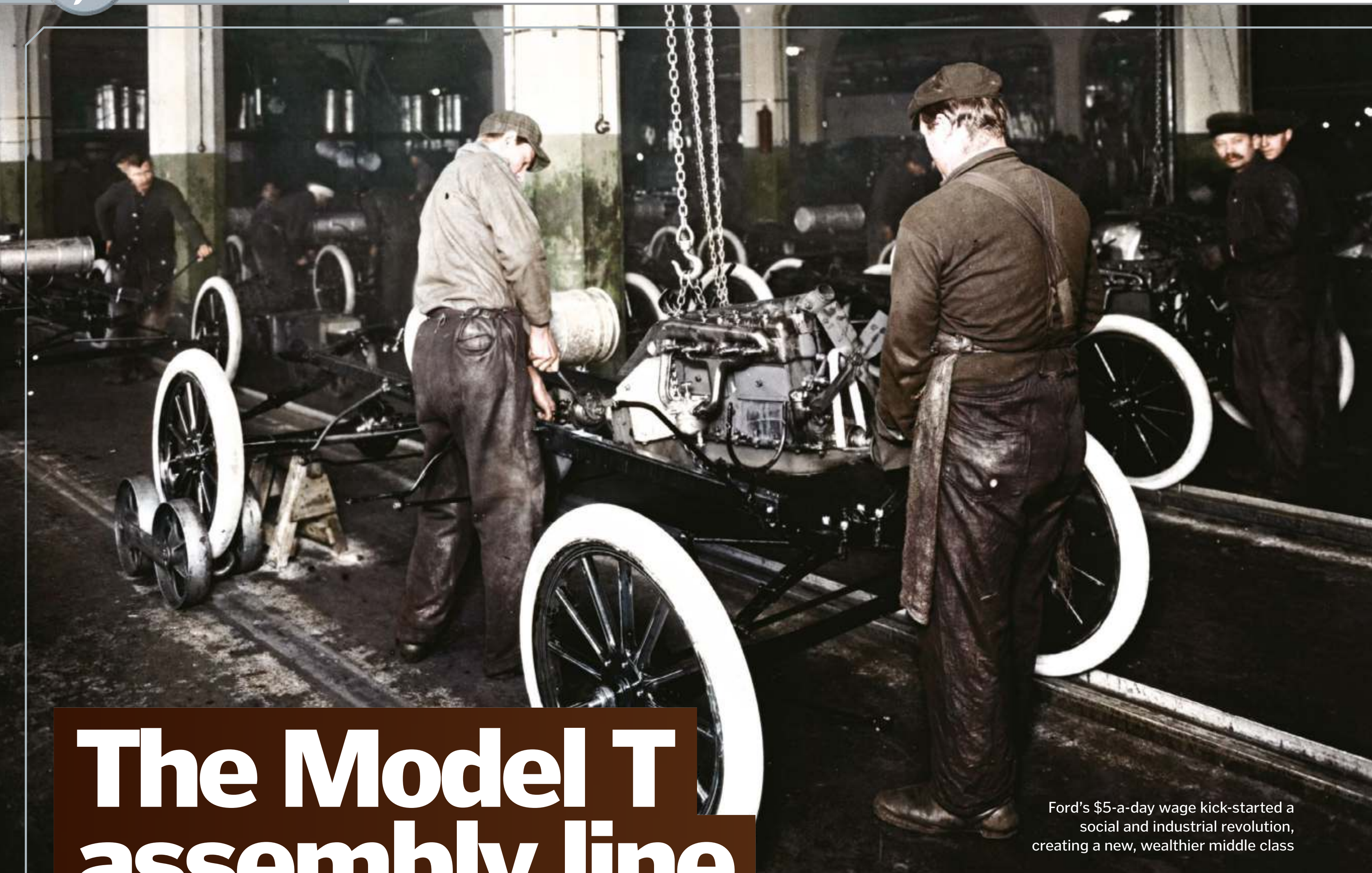
Early steamboats relied on paddle wheels rather than propellers for forward motion



Piston

Drive mechanism
The rods are designed so that they can turn the wheels while remaining perpendicular to the track.

Return pipe
Water that has condensed from cooled steam is collected and returned to the boiler.



Ford's \$5-a-day wage kick-started a social and industrial revolution, creating a new, wealthier middle class

The Model T assembly line

Henry Ford's pioneering manufacturing process put the world on wheels

41

Before Henry Ford opened the first moving assembly line on 7 October 1913 at the Highland Park Assembly plant in Michigan, car manufacturing was an incredibly slow and costly process. Ford's ambitious goal was to produce the highest number of cars at the lowest possible cost and in the shortest amount of time.

In the first rudimentary assembly line, an empty chassis was pulled across the factory floor using a rope and winch, with 140 workers positioned at various points along the 45-metre line to install the car's 3,000 different components. Each worker was trained to perform one particular task well, such as installing a radiator or a light, before the vehicle was moved on to the next station to have the next fitting attached.

The simplicity of the production line allowed unskilled employees to be hired, dramatically cutting the cost of employing solely skilled workers who would demand a much higher wage. This meant that Ford was able to increase the wages he paid his staff, which rose from \$2.34 to \$5 a day, a rise of more than double and one that made a hugely positive social impact.

The assembly line changed the face of the automobile industry and was continually refined to improve efficiency as much as possible. The Model T was the first vehicle to be produced with this method and the car's price soon fell from \$850 to less than \$300. Ford's template fast became the standard and, for the first time, a comfortable and reliable car was now widely available and affordable to the average American, cementing the Model T's intended reputation as a 'car for the masses'. Car ownership boomed and the age of the automobile began.

Ford's assembly line

The production process and components that created the famous Model T

Rails
The chassis was moved along the production line on rails before the wheels were added.

Suspension and axle installation
The Model T featured two leaf springs, one across each axle.

Component delivery
Parts were delivered to workers' stations by chutes and feeder lines.

Engine and fuel tank installation
The single-block engine design became an industry standard.

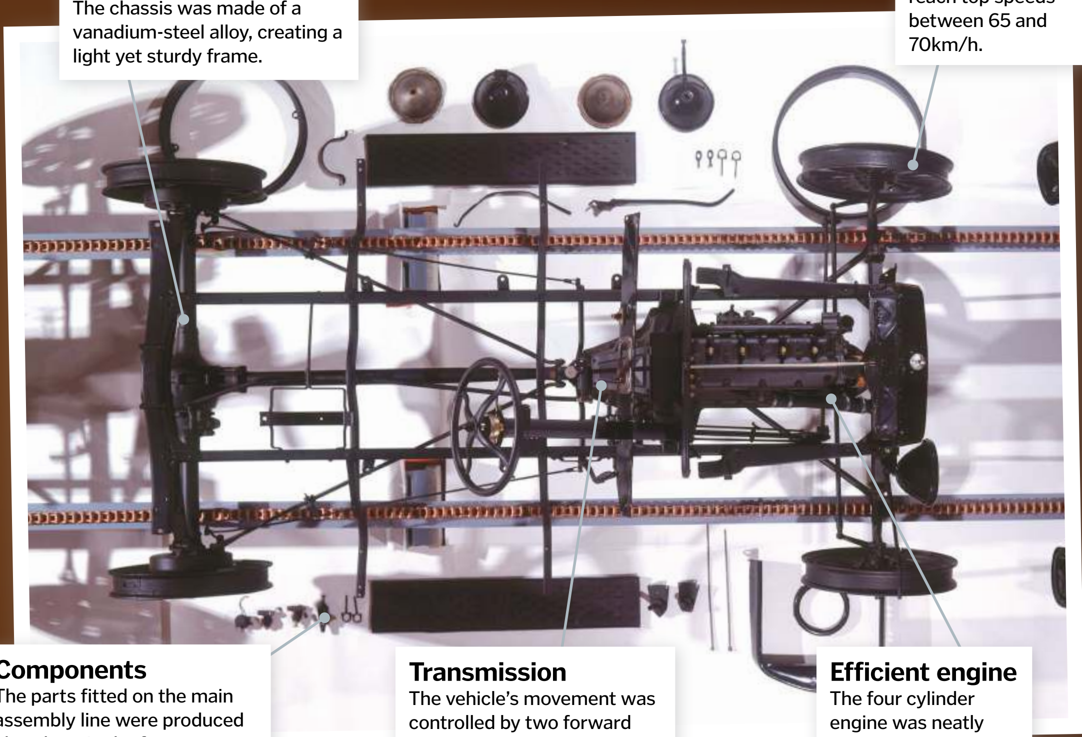
Dashboard, power system and steering installation
Contrary to other US vehicles at the time, the Ford Model T featured the steering wheel on the left-hand side, which became the norm.

An estimated 18.5 million Model Ts were sold worldwide

Ford declared that he would "build a motor car for the great multitude"

A motor for the masses

The simple mechanics that helped a nation to get behind the wheel



Light and strong
The chassis was made of a vanadium-steel alloy, creating a light yet sturdy frame.

Fast commute
The Model T could reach top speeds between 65 and 70km/h.

Components
The parts fitted on the main assembly line were produced elsewhere in the factory.

Transmission
The vehicle's movement was controlled by two forward gears and one reverse gear.

Efficient engine
The four cylinder engine was neatly cast in a single block.

"Ford's goal was to produce the highest number of cars at the lowest possible cost and in the shortest amount of time"

The evolution of success

The Ford Motor Company's assembly lines continued to improve

1954

By 1954 the models being manufactured in the Dearborn Assembly Plant, Michigan, were available in a multitude of colours.

1975

Ford workers at the Dearborn plant could later build and inspect their vehicles from beside the production line or from the pits below the rail.

2004

Seen here at the Flat Rock Assembly Plant, mechanisation of the assembly line led to an even more efficient production process.

Workers
Workers at their stations performed the same task on each car, meaning unskilled or low-skilled labourers could be employed.

Wheels and radiator installation

Painting the body
For many years the Model T was only offered in one colour. Ford remarked, "Any customer can have any colour he wants so long as it's black."

Fender installation
To complete the chassis, the fenders were added and the radiator and petrol tank were filled.

Upholstering and varnishing
The wooden parts of the body were varnished and the leather upholstery added.

Bonnet installation

Bodywork chain
The body of the car was put together on a second floor. The completed section would be lowered onto the chassis via a ramp, arches and ropes.

Body and chassis fixed together

Finishing touches
The last details were added before supervisors checked the car and engine tests were performed.

Commercial shipping 42

Five reasons why cargo ships are the world's most important mode of transport

EVERY YEAR, THE AVERAGE DISTANCE TRAVELLED BY ONE SHIP IS THREE-QUARTERS OF THE DISTANCE TO THE MOON AND BACK

50,000

Merchant ships transport trade goods internationally, manned by over 1 million workers

90%

OF ALL TRADE PRODUCE IS TRANSPORTED VIA CONTAINER SHIPS

SHIPPING IS THE LEAST ENVIRONMENTALLY DAMAGING FORM OF COMMERCIAL TRANSPORT

$2,700

THE ESTIMATED COST TO SHIP ONE STANDARD CONTAINER FROM MELBOURNE TO CALIFORNIA, COMPARED TO $20,000 BY AIR

Electric cars 43

How truly reliable eco-friendly automotive travel is becoming a reality

While the first small-scale electric car model was created as early as 1828, it's fair to say they haven't always had the best press. Expensive and often unreliable, as recently as 2001 the furthest one was able to travel was around 130 kilometres (GM's EV1). Despite concerns about global warming, high costs meant electric cars failed to truly take off.

However, things began to change in 1997 when the Toyota Prius – the world's first mass-produced hybrid passenger car – was first released in Japan before going global. Equipped with a nickel metal hydride battery, it became the best-selling hybrid of the decade.

But this was just a foreshadowing.

In 2006, Silicon Valley-based Tesla Motors began producing vehicles that could travel over 320 kilometres on a single charge. Chevy and Nissan soon followed suit, and investment by the US Energy Department has allowed companies to cut battery costs by about 50 per cent while still improving power, energy and durability. Today, in the US alone there are more than 234,000 electric vehicles and 3.3 million hybrids.

Tesla's Model S is one of the world's best-selling plug-in electric cars

Maglev trains 44

Why Japan's magnetic locomotive is a modern-day miracle

If you've never seen a train fly then you clearly haven't seen Japan's maglev trains. Thanks to electrically charged magnets that allow it to hover ten centimetres above the tracks, maglev (short for 'magnetic levitation') trains are able to move at much higher speeds than conventional trains due to the lack of friction. A Japanese maglev set a new speed record during a test when it hit 603 kilometres per hour.

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11th century
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20th century
King Edward I
13th-14th century
Roman legionary
2nd century BCE-5th
century CE
Gordon Highlander
19th-20th century
Red Army infrantyman
20th century
Pirate lord Ching Shih
18th-19th century
German tribesman
2nd century BCE-6th
century CE


Mexican cavalryman
20th century
Finnish machine gunner
20th century
British redcoat
17th-19th century
French knight
5th-15th century
German stormtrooper
20th century
US infantryman
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18th century
Ottoman Zouave
19th-20th century

HOW IT WORKS

A CLOSE ENCOUNTER

Wondrous habitats OF THE World

Filled with outstanding biodiversity, these beautiful pockets of Earth are extra special places

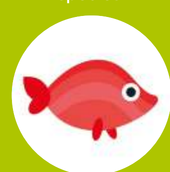
Reef hunter
A moray eel peers out of a nook in the coral, just one of thousands of marine species of the Coral Triangle.

The critically endangered hawksbill sea turtle nests on beaches throughout the Coral Triangle

6 of 7
species of sea turtle can be found in the Coral Triangle.

1.7%
The percentage of the Earth's oceans that the Coral Triangle covers.

605
species of coral make up the Coral Triangle. That's 76 per cent of all known coral species!



2,228
of the world's 6,000 coral reef fish species live here – that's 37 per cent!

25m
Average length of a blue whale, the largest animal to have ever lived, which visit the Coral Triangle

Biodiversity hotspots

Defined as an area that supports a high number of unique species, here are the hotspots across the world

The Coral Triangle

Covering 6 million square kilometres, this the most diverse marine ecosystem in the world

Connecting six nations, this huge 'triangle' of vibrant coral reefs is of incredible importance for ocean and human life alike.

These colossal reefs are teeming with life thanks to the huge amount of space for colonisation, specialisation and evolution and, of course, the promise of food. The sheltered reefs are also essential spawning and nursery grounds for migratory species that then range across the rest of the world's oceans.

Alongside marine life, humans also depend heavily on the Coral Triangle. The reefs are natural barriers that offer protection from storms in the Pacific. They also provide food and essential sources of protein for the islands and support industries such as tuna fisheries and the hugely lucrative tourist industry.

But this crucial ecosystem is under threat. Thanks to overfishing, destructive fishing methods, bycatch and global warming, the reefs and the vast amount of life that they support are in need of conservation like never before.

Hard coral secretes a skeleton of calcium carbonate, the stony, reef-building substance that supports entire ecosystems

> *"The sheltered reefs are also essential spawning and nursery grounds for migratory species"*

The largest big cats in the rainforest, jaguars are adept swimmers and will jump into the river to hunt fish, turtles and caiman

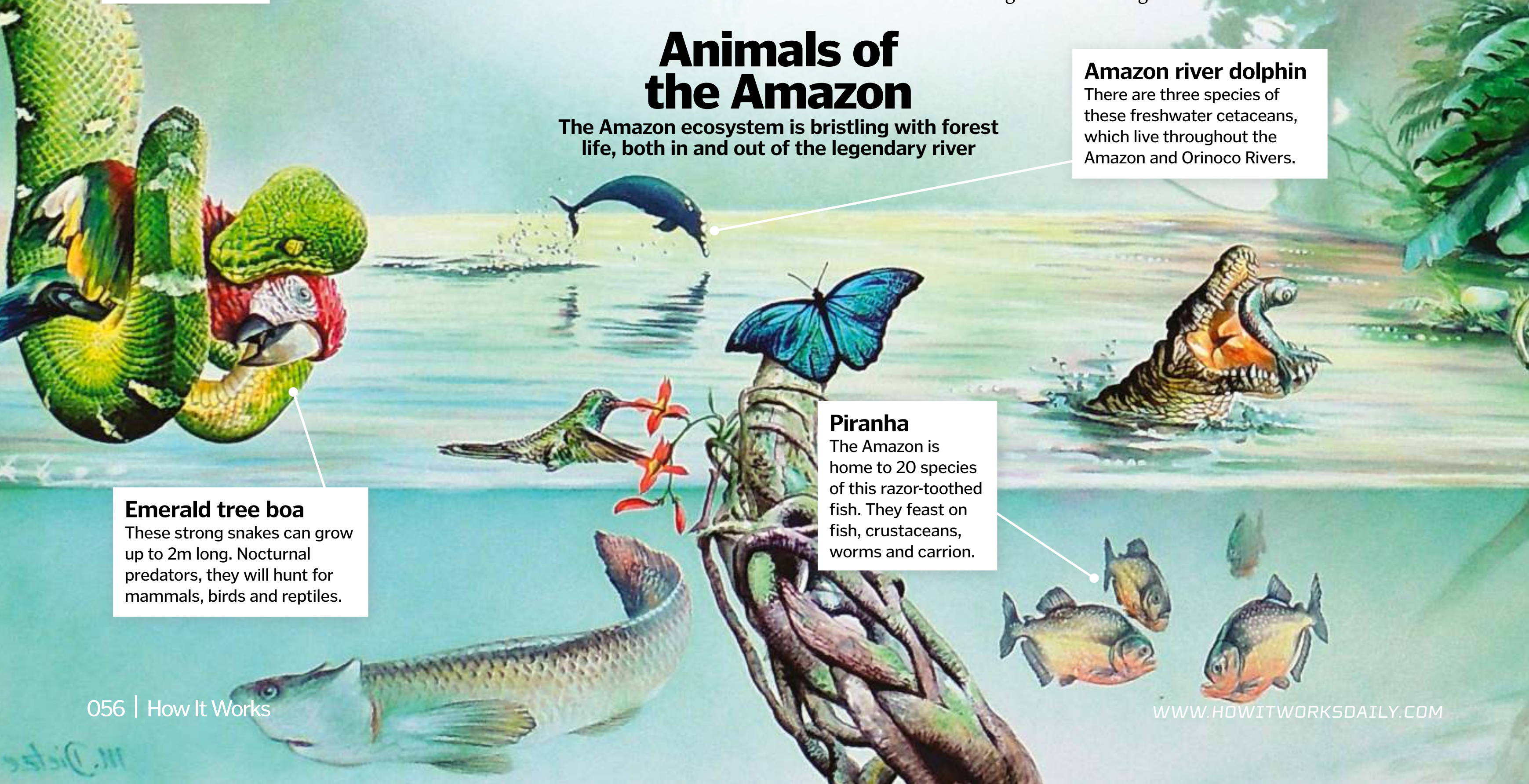
The Amazon

This collective biome of river and rainforest is the epicentre of Earth's biodiversity

46

The Amazon biome spans nine countries and contains almost 400 billion trees of 16,000 different species. It's a complex web of many ecosystems, including rainforests, savannahs, swamps, grasslands and flood plains. Despite covering roughly one per cent of Earth's surface, the Amazon is home to around ten per cent of all known species. It's incredibly biodiverse; there are more ant species on one tree in the Amazon Rainforest than there are in some countries!

The health of the Amazon is directly linked to the health of our planet. The trees that form it release around 20 billion tons of water as vapour every day, which brings rain to the continent. The rainforests contain 90-140 billion metric tons of carbon – which would otherwise be emitted into the atmosphere – and help to stabilise the world's climate. Deforestation is one of the many threats the Amazon faces, and it could result in the release of some of this carbon, which would accelerate global warming.



Animals of the Amazon

The Amazon ecosystem is bristling with forest life, both in and out of the legendary river

Ocelot
Twice the size of a house cat, these felines hunt rodents, fish and monkeys, taking to the trees as well as the river to hunt.

Amazon river dolphin
There are three species of these freshwater cetaceans, which live throughout the Amazon and Orinoco Rivers.

Emerald tree boa
These strong snakes can grow up to 2m long. Nocturnal predators, they will hunt for mammals, birds and reptiles.

Piranha
The Amazon is home to 20 species of this razor-toothed fish. They feast on fish, crustaceans, worms and carrion.

6.7km²
The size of the Amazon biome – that's twice the size of India!

1/5th
of Earth's fresh water is contained in the Amazon Basin.

20%
of the world's oxygen is produced in the Amazon rainforest. It's nicknamed the 'lungs of the world'.

Over 14 billion cubic metres
of water flows into the Atlantic Ocean every day from the Amazon River.

350
different ethnic groups live in the Amazon. Over 60 are still relatively isolated.

"There are more ant species on one tree in the Amazon Rainforest than there are in some countries"

Scarlet macaw
These brightly-coloured birds have specially adapted beaks for breaking open seeds. They are among the largest parrots in South America.

Sloth
With their super low metabolic rate, the sloths of the Amazon move through the trees at around 36m per day!

Green iguana
Living much of its life in the forest canopy, the green iguana is amongst South America's largest lizards, growing to around 2m long.

Tapir
Found across Central and South America, these able swimmers prefer to live near water. Although not exclusively nocturnal, they tend to forage at night.

Squirrel monkey
Feeding on the rainforest's bounteous fruits, insects and seeds, these monkeys live in groups and vocalise loudly to keep in touch.

There are 227 'dominant' tree species in the Amazon, one of which is the walking palm tree (pictured)

Svalbard Archipelago

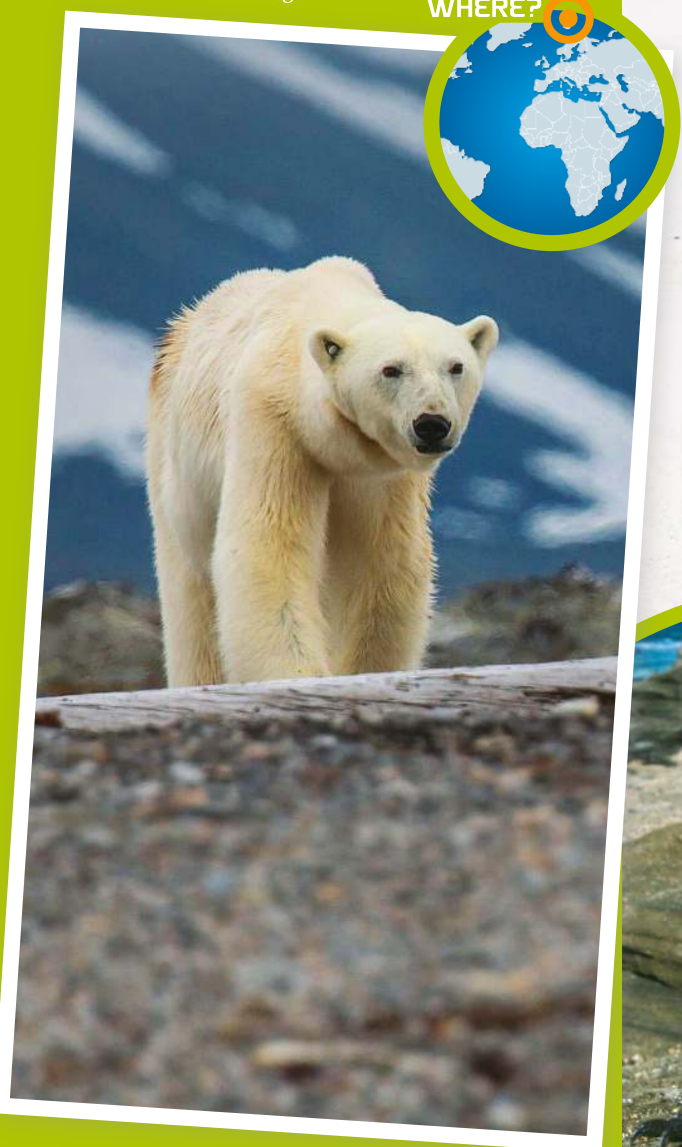
Situated between Norway and the Arctic, these islands host some unique wildlife

47

Thanks to a mix of environmental parameters and different habitats, this group of Arctic islands are home to some incredible animals.

In summer, when the ice and snow retreats, thousands of seabirds flock to the islands to feed on the rich fish pickings. Year-round residents include walruses, narwhal and plenty of seals, and when the sea ice arrives in the winter, polar bears can be seen on the prowl. In the winter snow, arctic hares and foxes sport bright white coats for camouflage.

WHERE?



Polar bears are the largest bear species on Earth. They use the sea ice to hunt for blubber-rich seals

"Year-round residents include walruses, narwhal and seals. When the sea ice comes, polar bears can be seen on the prowl"

Often found basking on the shore, the marine iguana feeds almost exclusively on marine algae

The Galápagos Islands

This archipelago of thirteen major islands is a 'showcase of evolution' both above and below the water

48

Around 1,000 kilometres into the Pacific Ocean from the Ecuadorian coast, the Galápagos Islands are a hive of endemic species. There are 13 major islands, five of which are inhabited by wildlife found nowhere else in the world.

Thanks to the confluence of three ocean currents, marine animals such as the blue-footed booby, marine iguana, Galápagos fur seal and Galápagos penguin thrive here. On land, plants such as mangroves, cacti and flowering shrubs bloom, while the ancient Galápagos tortoise roams the islands, sharing its home with many finch species made famous by the work of Charles Darwin. The sheer remoteness of these islands has allowed life to flourish independently, with evolution undisturbed by anything from the mainland.

The giant tortoise of the Galápagos is the longest-living vertebrate – the oldest known individual lived to 152!

The Sally Lightfoot crab is a total scavenger, feeding on the organic debris of the Galápagos beaches

Madagascar

The world's fourth-largest island has an amazing array of unique wildlife

49

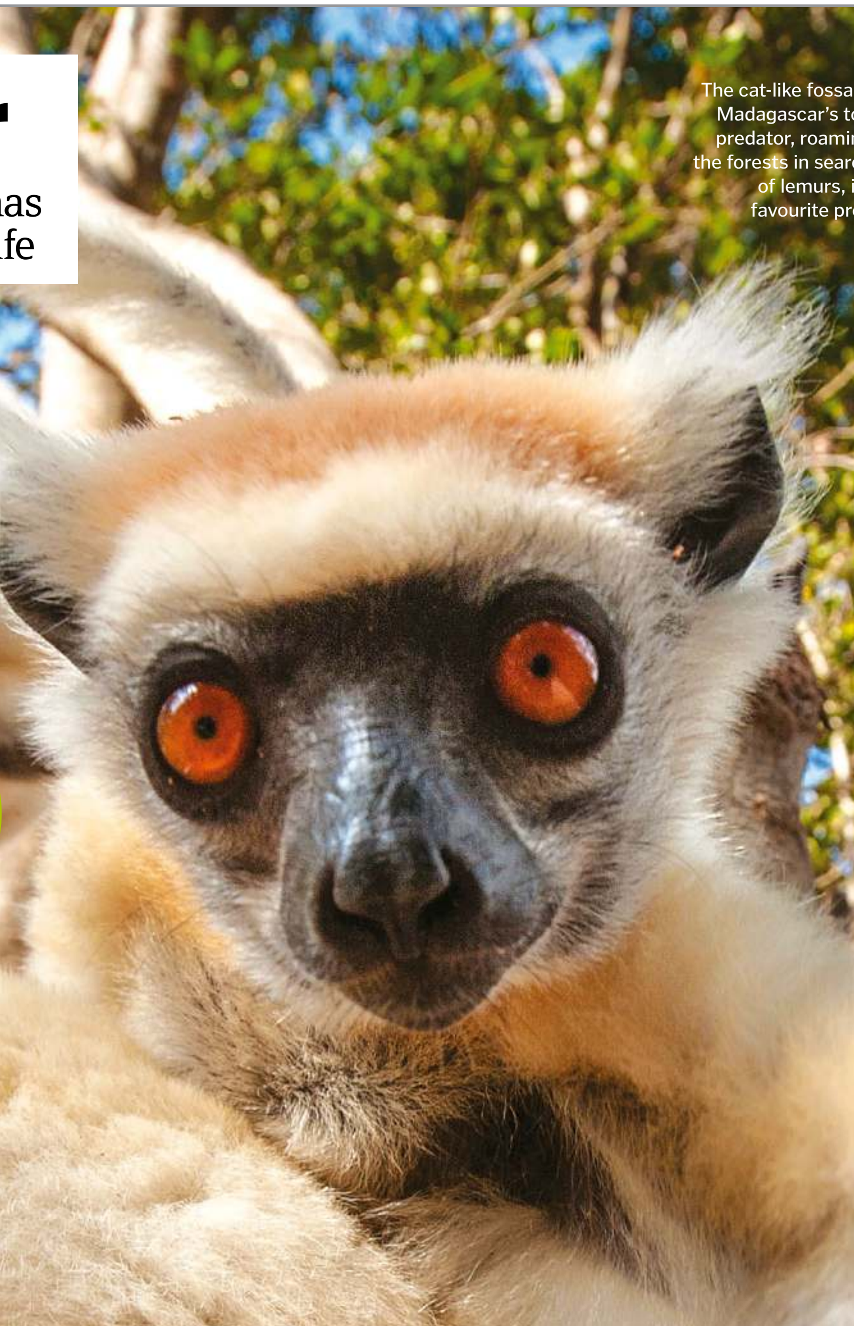
After splitting from the African continent around 165 million years ago, the island of Madagascar developed a diverse array of habitats, including rainforests, savannahs, tsingy (spiny rock formations), coral reefs, marshland and mangrove forests. These provide homes for a great number of amazing species.

There are 11,000 plant species that are only found here. Similarly, 95 per cent of the island's reptiles and 92 per cent of its mammals live nowhere else in the world!

There are many examples of convergent evolution, where animals evolve separately to fill the same niche, so they are totally unrelated but can look and act in similar ways!

WHERE?

"The island of Madagascar split from Africa around 165 million years ago"



Golden-crowned sifakas are medium-sized lemurs only found in a small area in the northeast of the island

The cat-like fossa is Madagascar's top predator, roaming the forests in search of lemurs, its favourite prey

Male panther chameleons from different areas of Madagascar exhibit different (yet equally vibrant) colourings

The Sundarbans mangrove forest

WHERE?

50

One of the world's largest mangrove systems is a haven for some unique and endangered species

Threats

This delicate ecosystem is threatened by deforestation, agriculture and the inflow of sewage and industrial pollution.

River delta

The salt-loving mangrove trees thrive on the tidal waterways of the Ganges-Brahmaptura-Meghna River Basin.

Endangered species

These thriving forests are home to the last surviving population of mangrove-dwelling Royal Bengal tigers.

Bay of Bengal

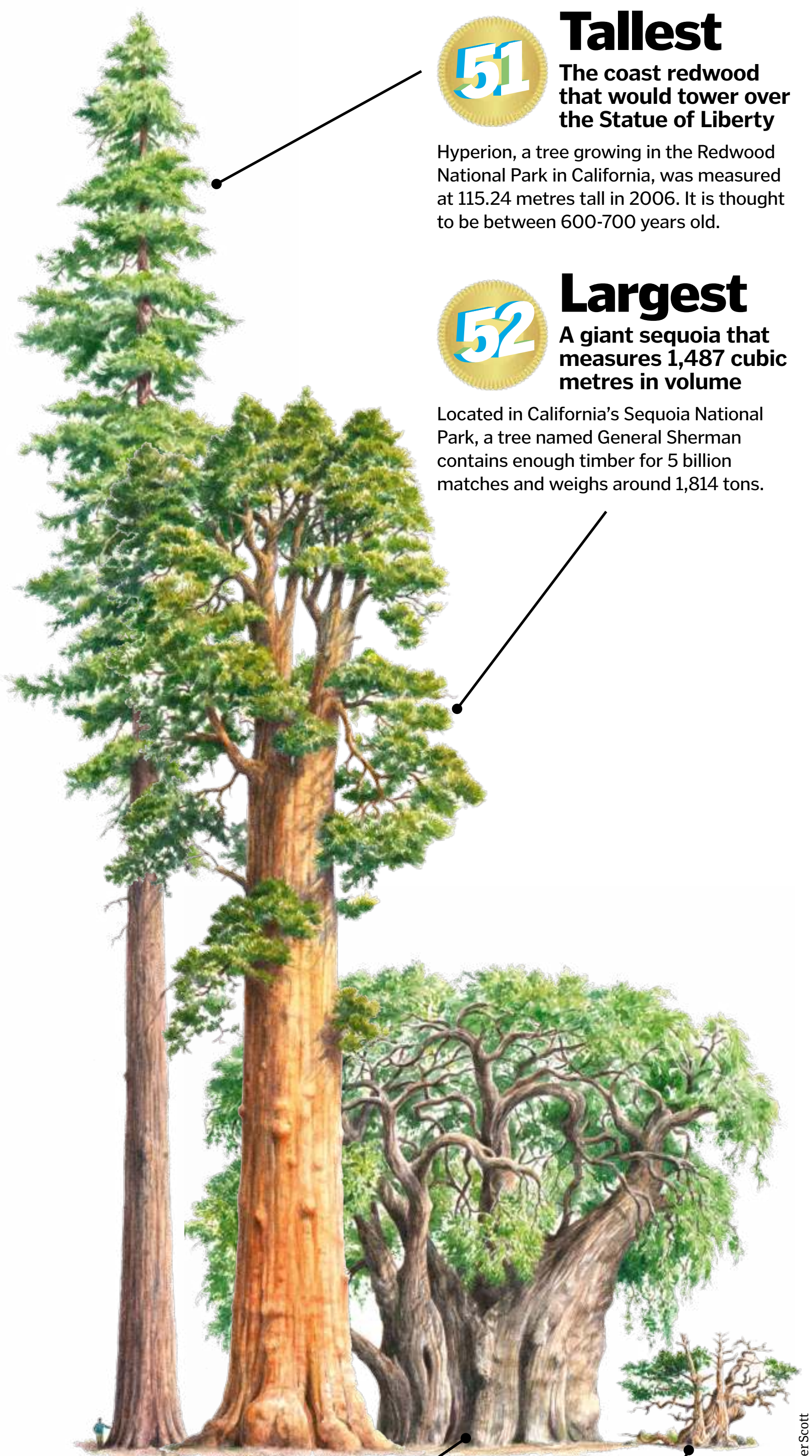
The Sundarbans forest covers a cluster of islands in the Bay of Bengal, spanning 10,000km² over India and Bangladesh.

Nursery grounds

The deep mangrove roots provide sheltered waterways and protection, making the Sundarbans an ideal nursery ground for many important marine species, such as tiger prawns.

The Sundarbans are home to Earth's largest crocodilian – the saltwater crocodile

Amazing trees



51 Tallest

The coast redwood that would tower over the Statue of Liberty

Hyperion, a tree growing in the Redwood National Park in California, was measured at 115.24 metres tall in 2006. It is thought to be between 600-700 years old.

52 Largest

A giant sequoia that measures 1,487 cubic metres in volume

Located in California's Sequoia National Park, a tree named General Sherman contains enough timber for 5 billion matches and weighs around 1,814 tons.

53 Widest

The Montezuma cypress tree 11.5 meters in diameter

An unnamed tree in Oaxaca, Mexico has a circumference of 36 metres, equivalent to ten medium-sized cars placed end to end in a circle.

54 Oldest

The bristlecone pine that was as old as Stonehenge

When a 5.1-metre tall tree called Prometheus was cut down from Mt Wheeler in Nevada in 1963, it was found to be approximately 5,200 years old.

55 Whale song

These marine mammals communicate with mysterious and complex melodies

In 1971, biologists analysed underwater recordings and found that the vocalisations made by humpback whales were repeated patterns of sound and so could be considered 'songs'. Several whale species, including blue and bowhead, have songs, but humpbacks are the best studied. The males in a particular population sing the same songs, which are constantly evolving, and these tunes can be shared between nearby whale populations. The reason why whales sing is still a mystery. The leading theory is that songs are for courtship rituals, as males will often sing at breeding grounds, but it is also possible that whales sing to navigate as a form of long-distance echolocation across the ocean.

56 Snowflakes

The process a snowflake goes through to become symmetrical and totally unique

When a very cold water droplet freezes onto a pollen or dust particle in the sky an ice crystal forms. Water vapour freezes onto this crystal as it falls, building new crystals that appear as arms. Snowflakes are symmetrical because their constituent ice crystals reflect the internal order of the water molecules as they solidify. Temperature and air humidity determine the crystal's shape as it falls, and as such, all snowflakes are unique because no two flakes fall in exactly the same path under the exact same atmospheric conditions.

The largest snowflake ever observed measured 38cm in diameter

Tectonic plates

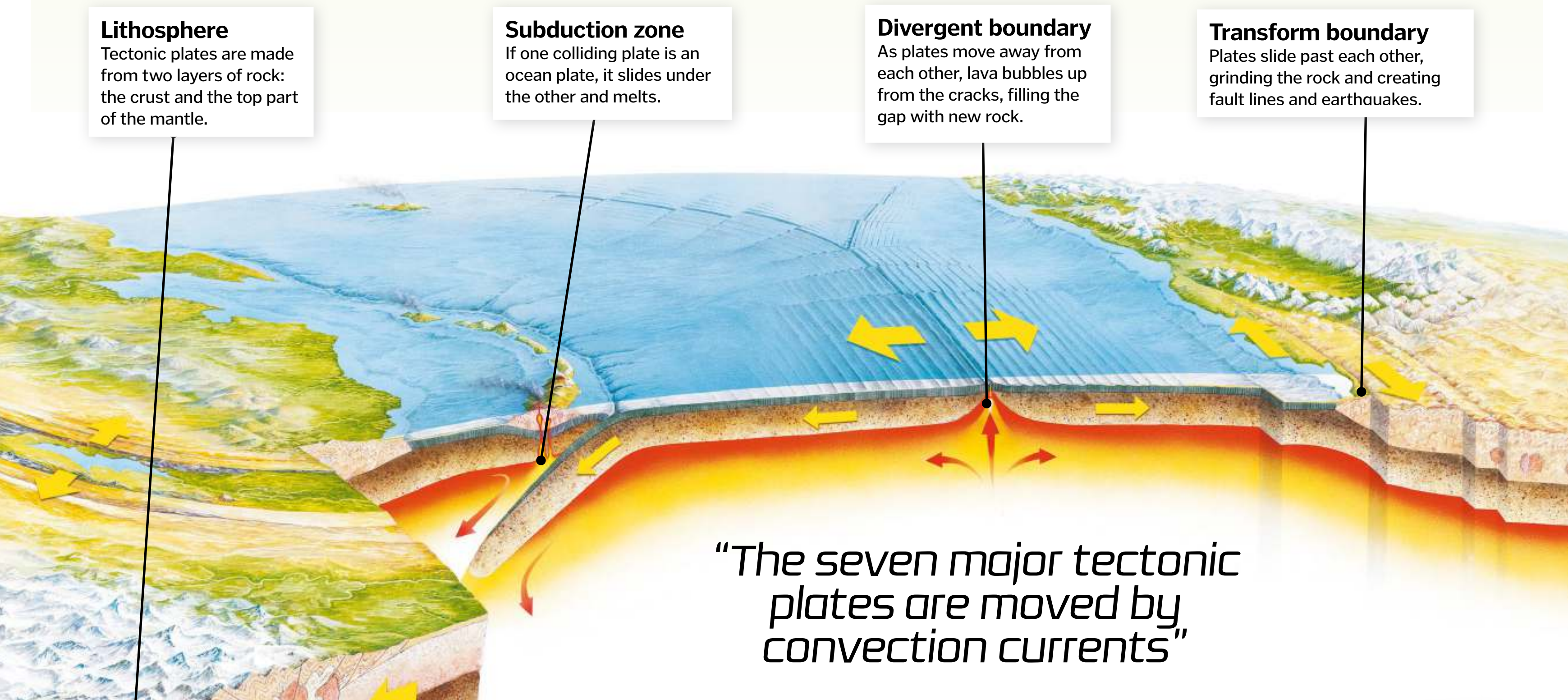
The face of our world as we know it was formed by the movement of vast floating islands

57 The lumps and bumps that coat the surface of our planet were once thought to be the effect of shrinkage. Like the cracked surface of a cake, scientists imagined that Earth had crumpled as it cooled, leaving behind deep valleys and tall mountains. But Alfred Wegener had another idea. To him, the continents looked like puzzle pieces that had slowly drifted apart. Decades after he first proposed the idea, it became clear that the continents sit on a series of moving plates that shift gently over the surface of the planet.

The outer part of the Earth, known as the lithosphere, is made from two rocky layers: the crust and the top of the mantle. Beneath the lithosphere is a layer of hot, viscous rock called the asthenosphere. It's so compressed that it stays solid but so close to its melting point that it flows like liquid.

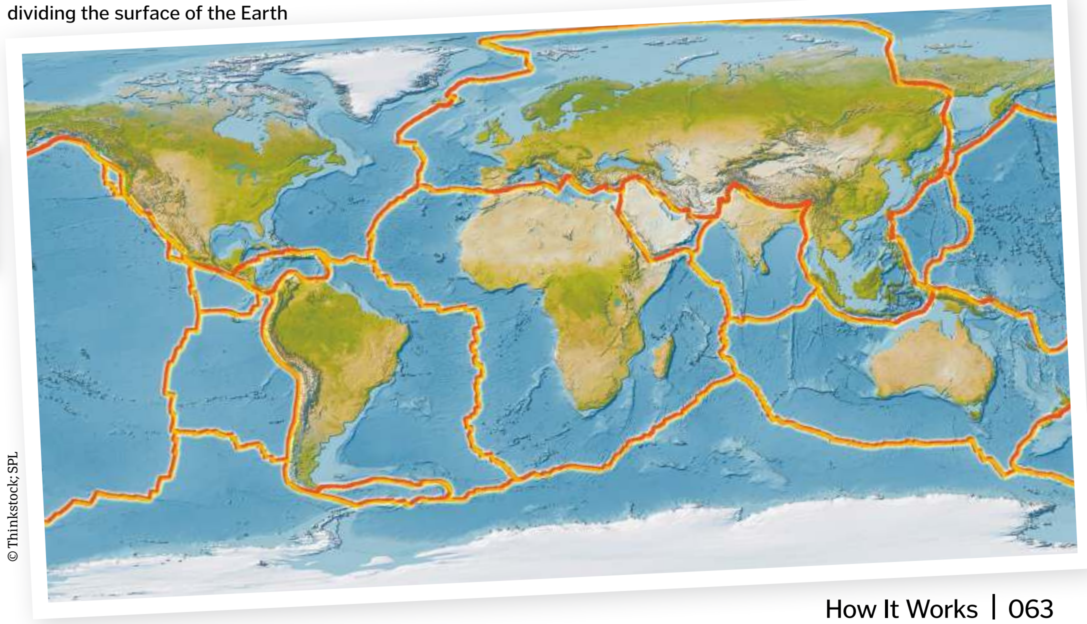
The lithosphere is divided into seven major tectonic plates, which slip over the asthenosphere as convection currents stir the molten rock below. They creep across the planet at a rate of up to ten centimetres per year, adding up to vast changes in the shape of the land.

Millions of years ago, the continents were all connected. Today, they are separated by oceans, with mountain ranges, valleys and fault lines marking where the separate plates collided.



"The seven major tectonic plates are moved by convection currents"

There are seven major tectonic plates dividing the surface of the Earth



Nature's light shows

Discover the living creatures and atmospheric conditions that can create some of the most spectacular illuminations on Earth

58 Lightning

Collisions between water droplets and particles of ice in storm clouds create a strong electric field, which separates atoms into positively charged protons towards the top of the cloud and negatively charged electrons towards the bottom. Eventually the charge builds up so much that electrons shoot towards the protons within the cloud or towards the positively charged ground in a flash of lightning.

59 Auroras

In space, charged ion and electron particles are constantly escaping from the Sun's gravitational field and travelling towards Earth at high speed. Most of them bounce off the Earth's magnetic field, but some are funnelled through its weak spots by the North and South Poles. They then collide with oxygen and nitrogen atoms in the Earth's atmosphere, causing them to give off particles of light called photons. Depending on where the collision takes place in the atmosphere, these photons appear as different colours.

60 Bioluminescent phytoplankton

Various species of phytoplankton produce light, but the most common are dinoflagellates. Movement of predators within the water likely starts a chemical reaction, which causes a protein called luciferin to produce a bright blue light. This is thought to act as a form of defence against predators.

Light pillars

61

During the day time, flat ice crystals in the upper atmosphere can sometimes reflect the light from the Sun, creating a 'Sun pillar'. However, when temperatures are below zero, these ice crystals can sometimes form nearer to the ground. There they can reflect light from streetlights and houses to create light pillars.

Fireflies

62

The cells inside a firefly's abdomen contain the chemicals luciferin and adenosine triphosphate, as well as the enzyme luciferase. When these ingredients mix with oxygen, which is supplied to the cells through a tube in the insect's abdomen, they emit light. Either by nerve cells or by controlling the flow of oxygen, the bug can turn the light on and off in quick bursts. In young firefly larvae, this light warns predators that the insect may contain toxic chemicals, while in adults it is used for selecting a mate.

Glow worms

63

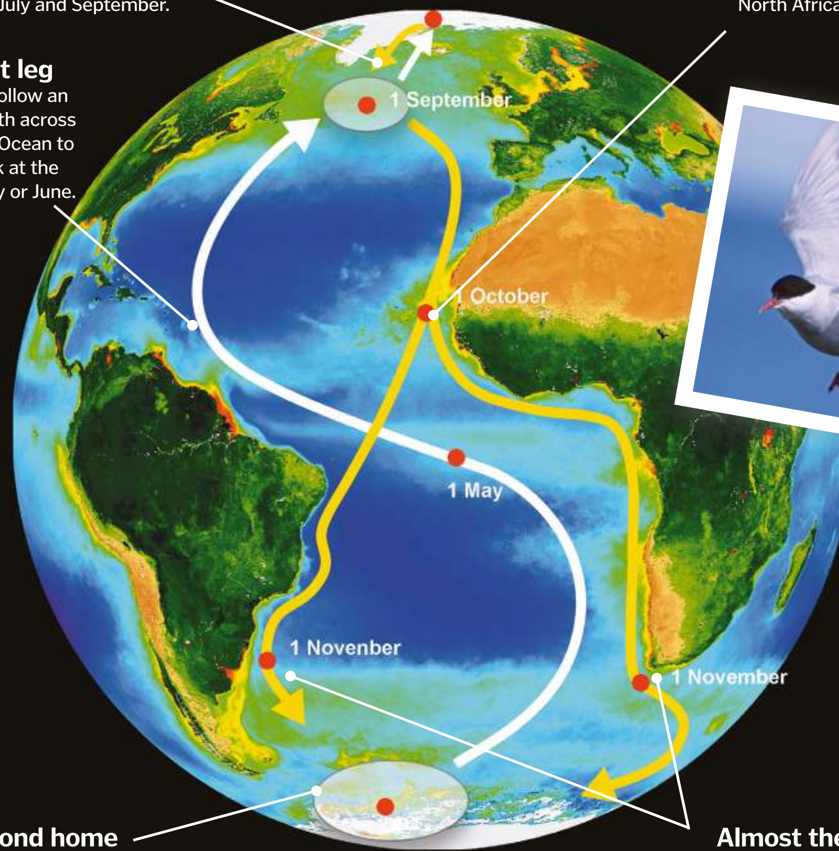
Glow worms are actually bioluminescent beetles, and they produce light in the same way that fireflies do. Only adult females of the species glow, as they use their light to attract flying males for mating.

A record-breaking migration

The tiny birds that can travel the equivalent of two trips around the world each year

64 After spending the northern spring and summer months along the northern coasts of Eurasia and North America, Arctic terns travel south to experience a second summer in Antarctica. Then, when the southern autumn arrives, they travel back up north again to breed. This epic pole-to-pole migration is the longest of any bird and has recently been mapped by fitting the animals with tiny trackers. One bird was found to have made a 96,000-kilometre round trip between the Farne Islands in Northumberland, UK and Antarctica, the longest migration ever to be officially recorded.

Over its lifetime the tiny bird, which weighs less than an iPhone, could fly as far as 3 million kilometres, the equivalent of nearly four trips to the Moon and back!



The journey begins
The birds set off from their Arctic breeding grounds between July and September.

The last leg
They then follow an S-shaped path across the Atlantic Ocean to arrive back at the Arctic in May or June.

Pit stop
At the beginning of October they arrive at the coast of North Africa.

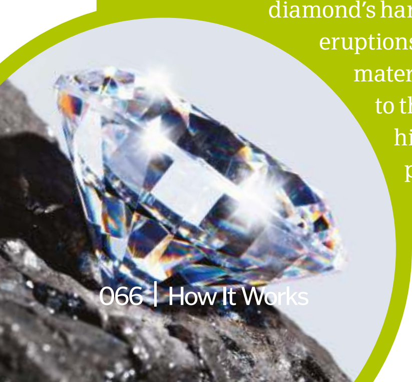
Second home
From late November until the end of March they live in the Weddell Sea of Antarctica.

Almost there
They continue down the coast of Africa or South America, depending on wind direction.

Diamonds

Find out how carbon atoms form crystal-clear diamonds

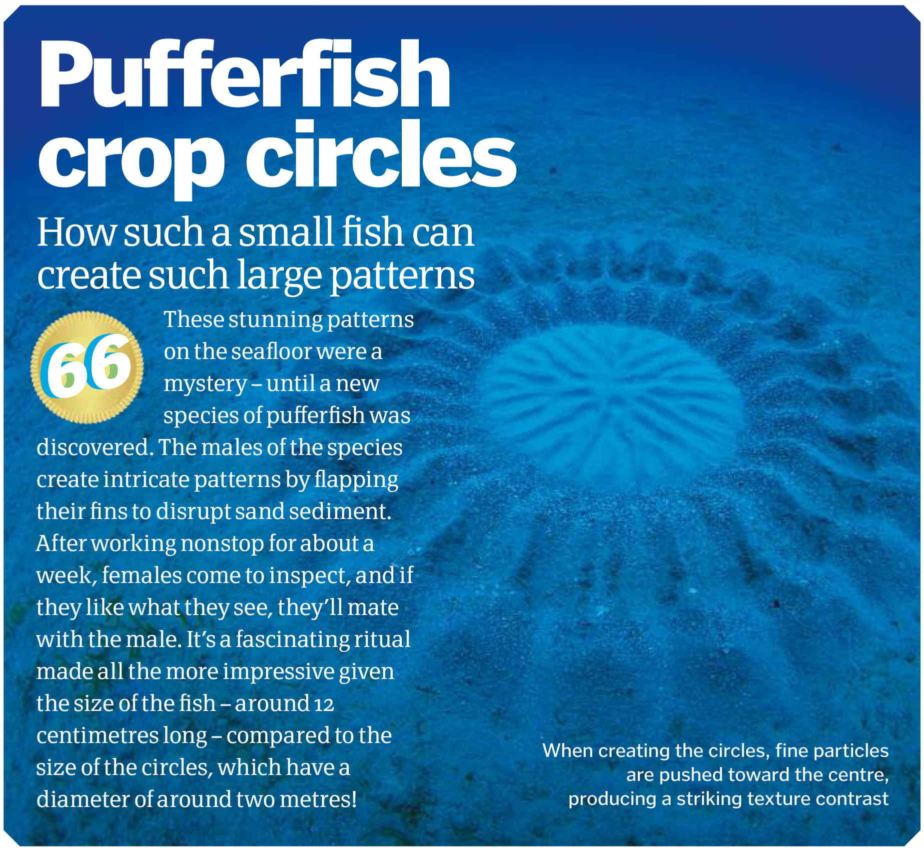
65 Diamonds are made of carbon, the same element that constitutes grey-black graphite. They owe their transparency to their unique formation process, which affects the arrangement of their atoms. About 160 kilometres below the Earth's surface, the combination of extreme heat and pressure allows carbon atoms to bond together, such that each atom forms a covalent bond to four others. This structure allows light to pass straight through and is very strong, contributing to the diamond's hardness. Volcanic eruptions later transported material from the mantle to the Earth's surface at high speed, helping to preserve the diamond's form.



Pufferfish crop circles

How such a small fish can create such large patterns

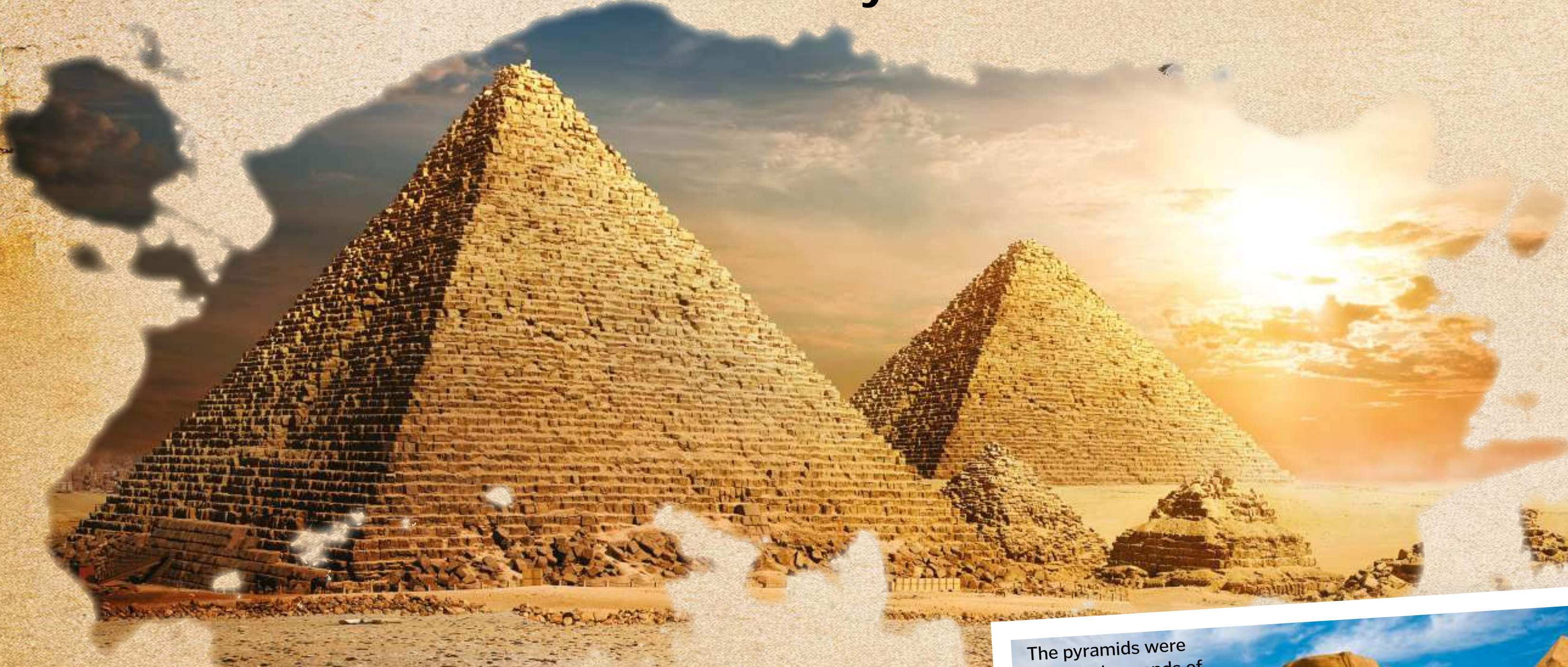
66 These stunning patterns on the seafloor were a mystery – until a new species of pufferfish was discovered. The males of the species create intricate patterns by flapping their fins to disrupt sand sediment. After working nonstop for about a week, females come to inspect, and if they like what they see, they'll mate with the male. It's a fascinating ritual made all the more impressive given the size of the fish – around 12 centimetres long – compared to the size of the circles, which have a diameter of around two metres!

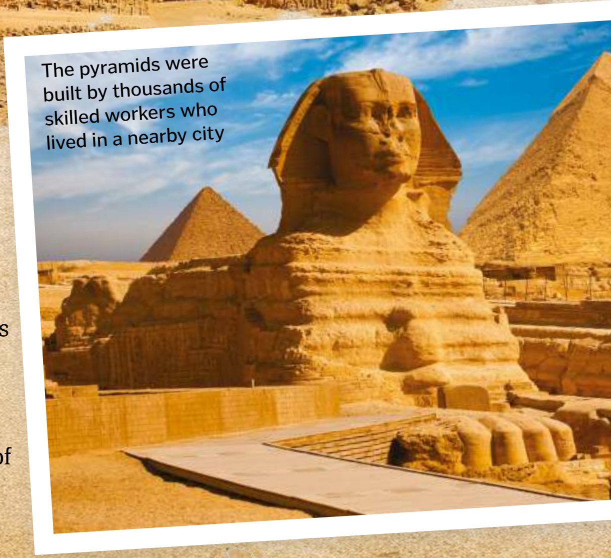


When creating the circles, fine particles are pushed toward the centre, producing a striking texture contrast

10 WONDERS OF THE ANCIENT WORLD

Take a tour of history's greatest human-made landmarks and discover how they were built





The pyramids were built by thousands of skilled workers who lived in a nearby city

The Pyramids of Giza and the Sphinx

The mystery of ancient Egypt's monumental feat of engineering

67

Built between 2589 and 2504 BCE, the three Pyramids of Giza served as extravagant tombs for ancient Egyptian pharaohs, large enough to house everything they would need in the afterlife. The largest, constructed for the Pharaoh Khufu, consists of 6.5 million tons of stone, some in blocks as heavy as nine tons each. However, no one quite knows how they were moved into position.

One theory is that a system of sledges, rollers and levers were used to haul the blocks up a slope that was increased in height as the pyramid grew. Meanwhile, the Sphinx, which stands close to the pyramids, was carved out of the limestone bedrock of the Giza Plateau.

The Great Wall of China

Incredible manpower and tasty materials helped construct the world's longest wall

68 Although the first sections of border walls had been built in the 8th century BCE, it wasn't until 220 BCE that Emperor Qin ordered for them to be joined up as a protective barrier. He set 300,000 soldiers plus many more peasants and prisoners to work constructing the wall from stone, soil, wood and even sticky rice, which helped hold the bricks together. The materials were transported to the site by hand or using wheelbarrows, ropes and animals.

Approximately 400,000 workers died during the Great Wall's construction

21,196.18km
Full length of the Great Wall

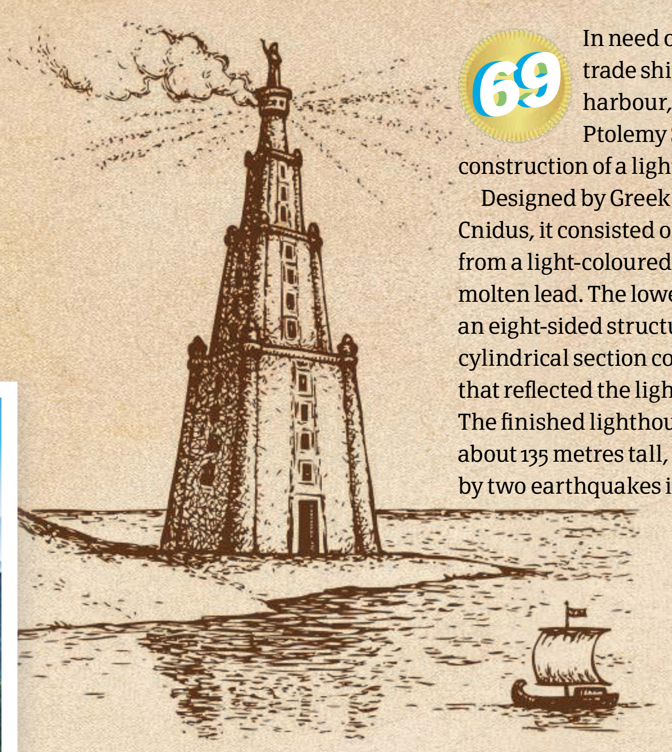
Equivalent to five times the width of the US

100 million tons
of brick, stone and mud were used to build it

14 metres
The tallest section is equivalent to the height of three buses

Pharos of Alexandria

The design and destruction of the world's first and most famous lighthouse



69 In need of a method for guiding trade ships into Alexandria's busy harbour, the Egyptian ruler Ptolemy Soter commissioned the construction of a lighthouse in around 280 BCE.

Designed by Greek architect Sostratus of Cnidus, it consisted of three levels, each built from a light-coloured stone and reinforced with molten lead. The lower square level supported an eight-sided structure, on top of which sat a cylindrical section containing a curved mirror that reflected the light from a fire into a beam. The finished lighthouse is thought to have been about 135 metres tall, but was reduced to rubble by two earthquakes in the 14th century.

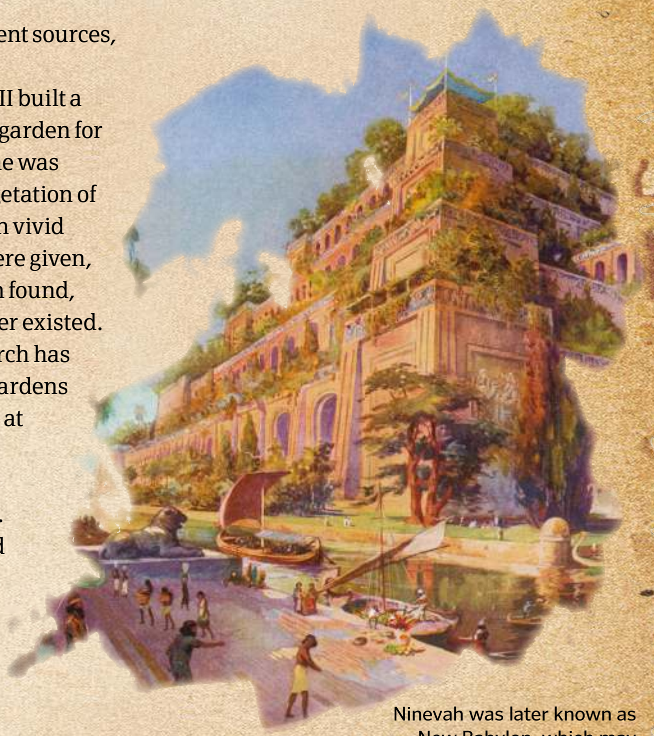
The Pharos took 12 years and a considerable amount of slave labour to construct

The Hanging Gardens of Babylon

A towering green oasis with a somewhat misleading name

70 According to ancient sources, Babylonian King Nebuchadnezzar II built a luscious hanging garden for his wife in 600 BCE because she was homesick for the beautiful vegetation of her native Media. But although vivid descriptions of the gardens were given, no physical evidence has been found, leading many to believe it never existed.

However, a more recent search has discovered that the hanging gardens may not have been in Babylon at all, but were instead built a century earlier in the city of Ninevah by King Sennacherib. It is thought they were planted on a series of terraces and an Archimedes' screw device was used to douse them with 300 tons of water a day.



Ninevah was later known as New Babylon, which may explain the confusion over the garden's exact location

"The hanging gardens may not have been in Babylon at all"

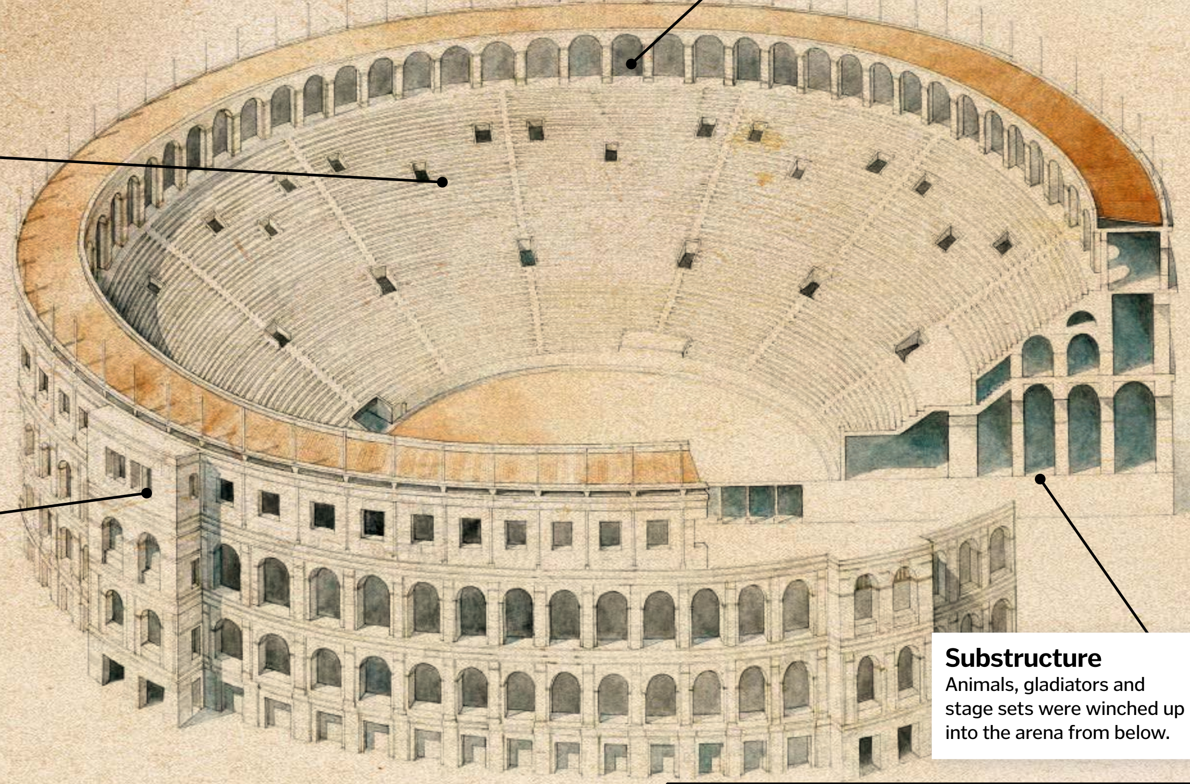
The Colosseum

Ingenious inventions and designs made the world's largest amphitheatre possible

71

In 80 BCE, after less than ten years of construction, Rome's enormous entertainment venue was completed. A pioneering feat of enginering, it would go on to host bloody gladiator battles, re-enactments and executions for four centuries.

The innovative four-tiered design of multiple vaulted arches provided plenty of support without adding excess weight and enabled more than 100,000 slaves to build it in simple, standardised parts. The recent invention of concrete also added strength, helping it hold crowds of more than 50,000 people at a time.



Awnings
Wooden masts supported awnings that shaded the audience from the Sun.

Seating
The tiered seating and elliptical design ensured everyone had a good view.

Crowd control
Almost 80 separate arched entrances allowed the crowd to enter and exit with ease.

Substructure
Animals, gladiators and stage sets were winched up into the arena from below.

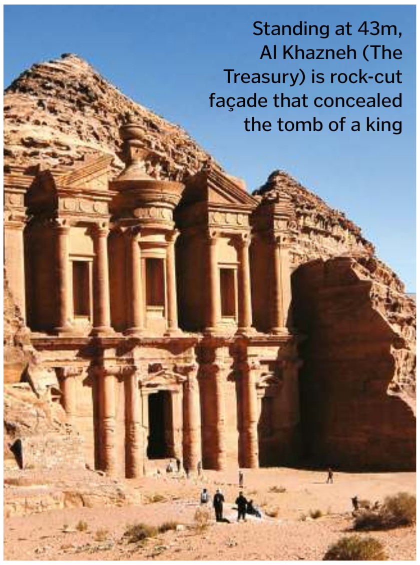
Petra

A unique 'Rose City' carved out of Jordan's desert rocks

72

Half-built and half-carved from the pink sandstone that inspired its colourful nickname, Petra was established as the capital of the Nabataean Kingdom in 400 BCE. As a busy trading hub, it was once home to around 20,000 people, but getting access to water was difficult in the middle of the desert.

The Nabataeans solved this problem by constructing an elaborate water management system featuring cisterns, reservoirs and dams that conserved seasonal rains. They chiselled their buildings out of the cliffs by carving steps into the surrounding rock, providing them with safe ledges to work from, and ensured important monuments aligned with the sunrise on winter solstice.



Standing at 43m, Al Khazneh (The Treasury) is rock-cut façade that concealed the tomb of a king

Banaue Rice Terraces

A giant staircase of rice fields built by hand

73

More than 2,000 years ago, the indigenous people of Ifugao in the Philippines came up with an ingenious method for farming on steep terrain. With no tools available, they carved a series of terraces out of the mountain, bordering them with walls of mud and stone. They then harvested water from the forests on top of the mountain, flooding the individual fields so that rice could grow. This method of farming and sustaining the terraces has since been passed down through the generations and is still practised today.

The rice terraces can be found in the Cordillera Mountains

Machu Picchu

The amazing engineering found in the Inca's lost city

74 Meaning 'old mountain' in the native Quechua language, Machu Picchu stands 2,430 metres above sea level in the Peruvian Andes. Only recently rediscovered in 1911, the city was built by the Inca people in the 15th century and then abandoned 100 years later when their empire was conquered by the Spanish. As the Inca had no written language, there are no records indicating the purpose of the site, but many archaeologists believe it was a royal estate used by leaders.

Set on the steep mountain slopes, the 200 buildings were constructed using a dry-stone technique without mortar. Blocks of granite were precisely cut and tightly slotted together like a jigsaw, leaving cracks so small even a knife could not penetrate them.

"Machu Picchu stands 2,430 metres above sea level in the Peruvian Andes"

Machu Picchu features palaces, plazas, temples, homes and an irrigation system

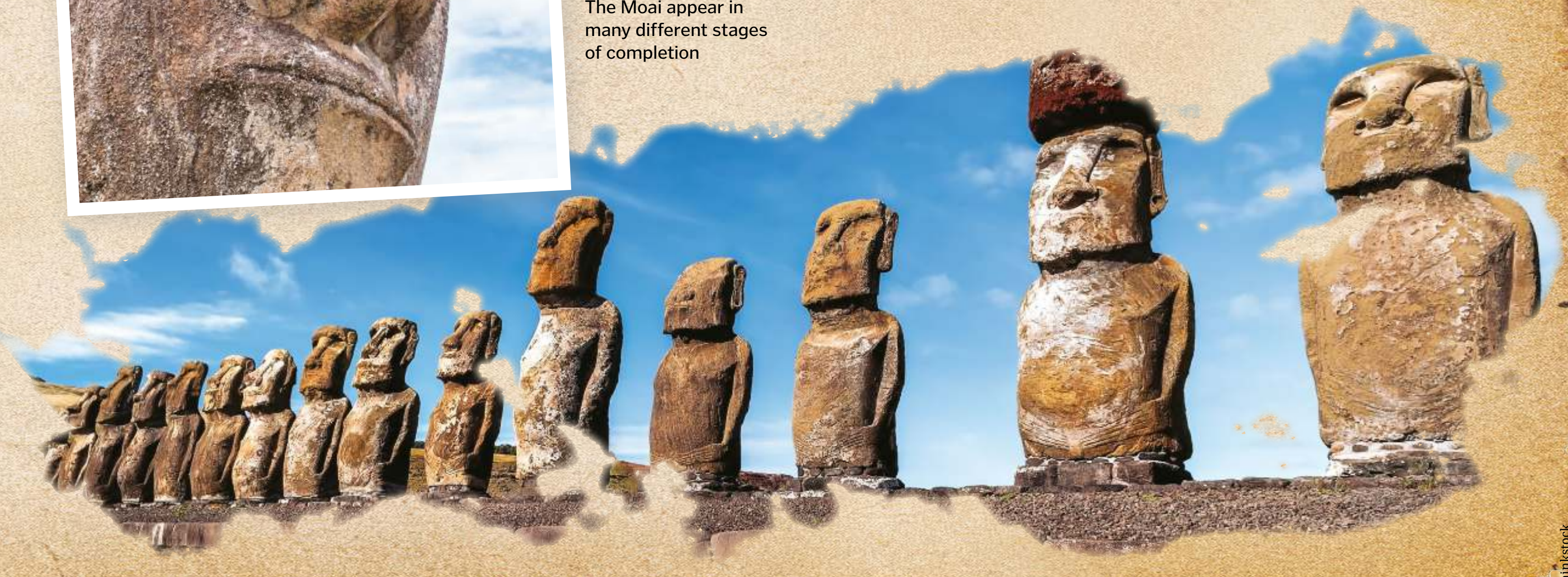
Easter Island statues

The giant stone heads that required a lot of heavy lifting

75 In the middle of the Pacific Ocean, almost 900 enormous statues called Moai can be found surrounding the Chilean island of Rapa Nui, the original name given to Easter Island by its Polynesian settlers. They were made by the Polynesians sometime between the 12th and 17th century, and are thought to represent their dead ancestors.

Despite being carved out of a light, porous rock called tuff, which is formed by compacted volcanic ash, they each weigh several tons, and exactly how they were moved into position still remains a mystery.

The Moai appear in many different stages of completion



Stonehenge

A prehistoric monument helping us to uncover the secrets of the past

76 In the Wiltshire countryside of England stands one of the most iconic and oldest human-made landmarks in the world.

Built over thousands of years, Stonehenge is the only surviving stone circle of its kind and has become a site of incredible archaeological importance. Although it has revealed a lot about certain practices of the past, the structure is still shrouded in mystery, mainly because we still can't be sure what it was built for.

The most popular theory is that it was a prehistoric temple, as the stones are precisely aligned with the movements of the Sun across the sky, which has special religious significance. What we do know is that its construction began in 3100 BCE, when a large circular ditch was dug using tools made from antlers. Around this time, the site was used for burials; in fact it's the largest late Neolithic cemetery in the UK.

In 2500 BCE, the stones were erected, having been worked into shape and smoothed using sarsen and flint hammerstones, and a few hundred years later were rearranged into their final position. Over the years many of the stones have toppled or been removed, leaving Stonehenge in its current state.

Superhenge

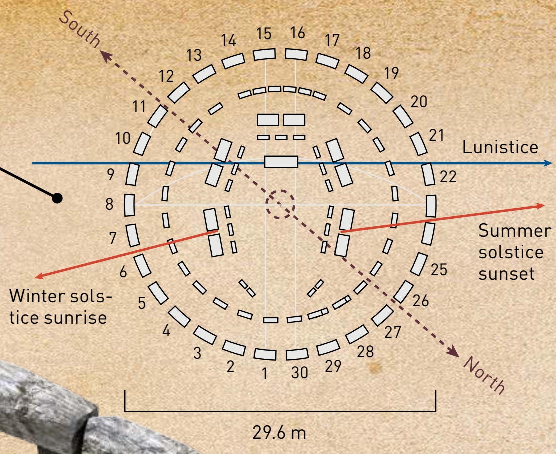
In 2015, scientists found what they thought was another stone monument, five times the size of Stonehenge, buried less than three kilometres away from the iconic landmark. Dubbed a 'superhenge', it was detected using ground-penetrating radar and believed to feature more than 100 stone monoliths.

However, when a dig was conducted, archaeologists instead found a series of deep pits that once held large wooden poles. The site was originally home to the people who built Stonehenge and the poles were erected when they left, perhaps as a memorial. However, they were later removed, and the pits were filled with chalk and covered over with a dirt bank.

The superhenge monument featured wooden poles, not large stones as previously thought

The Henge completed

Discover how Stonehenge might have looked in 2200 BCE



Alignment
The main axis of the stones line up with the sunrise of the summer solstice and the sunset of the winter solstice.

"Stonehenge is the only surviving stone circle of its kind"

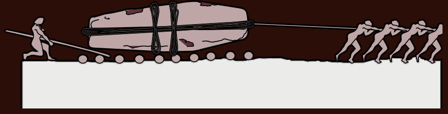
Alter stone
Unique to the site, this stone is made from a type of old, red sandstone and comes from the Senni Beds in south Wales.

Lintels
The horizontal stones on top of the outer ring were tightly slotted together using tongue and groove joints.

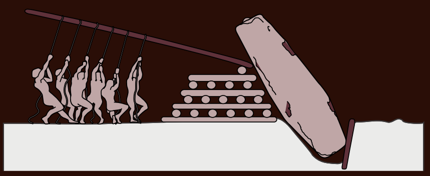
Assembling Stonehenge

How might the structure have been put in place with primitive tools?

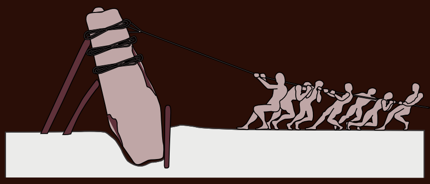
Transportation
The stones were dragged to the site on rollers and sledges, and some even came on rafts down the River Avon.



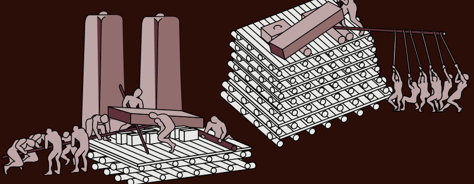
Positioning
The stones were placed in large holes with sloping sides and lined with wooden stakes at the back.



Raising the stones
Ropes, a wooden A-frame and sheer manpower were used to pull the stones upright, then the hole was packed with rubble.



Placing the lintels
Timber platforms were used to lift the horizontal lintels into position before they were placed on top of the upright stones.



The Panama Canal

77

The epic project that cut through a continent to connect the Atlantic and Pacific Oceans

77km
Total length of the canal, which features 12 locks.

34 years
The time it took to complete the project, started by the French in 1880 and finished by the US in 1914.

12,650km
The estimated distance saved by using the canal for journeys that would otherwise have to go around Cape Horn at the tip of South America.

10 hours
Average time it takes to travel through the canal, compared to the three-week journey around Cape Horn.

14,000
The average number of vessels that pass through the canal every year.

£3.8 billion
Estimated cost of the expansion project completed in 2016, which doubled shipping capacity.

The Bombe

The electro-mechanical device that cracked the Enigma Code and helped the Allies win WWII

78

The Bombe was a machine developed by mathematician Alan Turing and his team at Bletchley Park during World War Two. It was used to decipher secret German military communications, which had been encrypted to produce what was believed to be an 'uncrackable' code.

Each of the Bombe's rotors analysed 17,500 potential combinations at rapid speeds as it mimicked the settings inputted into the enemy ciphers. The Bombe worked logically to rule out incorrect configurations until it finally found the correct sequencing of the coded communications.

At its peak, approximately 4,000 messages were decrypted per day, giving the Allies the upper hand. It is believed that cracking the Enigma Code shortened the war by up to two years.

Engineer Harold Keen helped design the Bombe and oversaw construction

Gutenberg's printing press

The groundbreaking invention that facilitated the mass production of literature

79

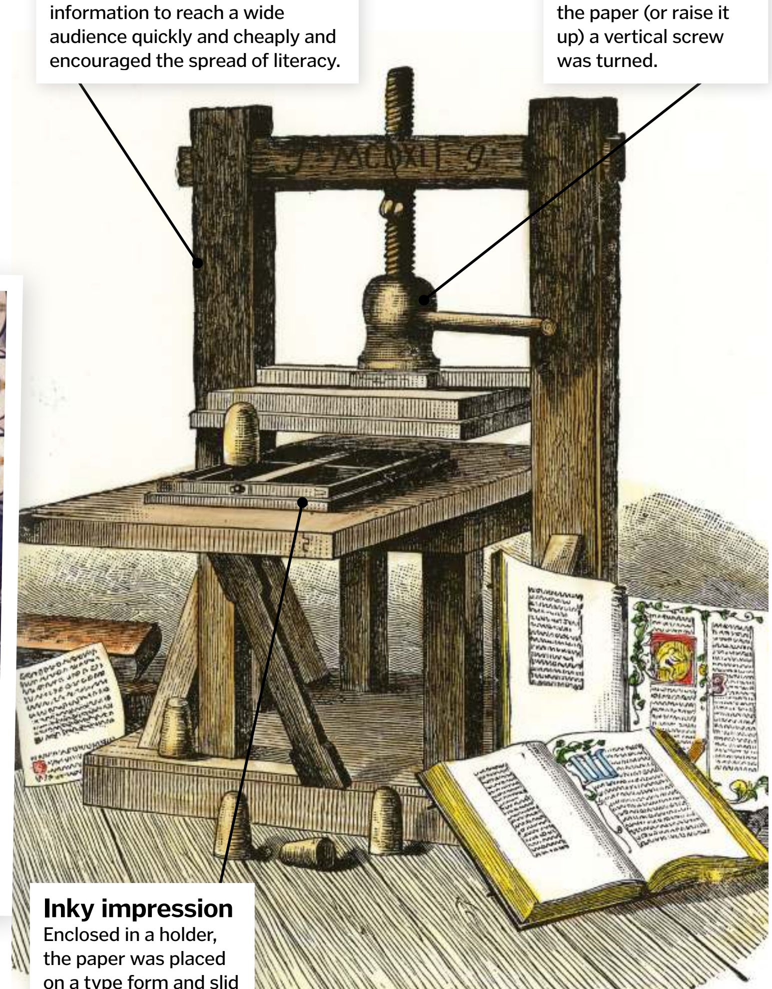
In the 15th century, a German goldsmith and craftsman named Johannes Gutenberg changed the world. His printing press was the first moveable type printing system, allowing information to be distributed much more efficiently than ever before.

Gutenberg's mechanism consisted of a handle that turned a screw. Attached to the screw was a wooden rectangular press, which had individual cast metal letters and punctuation fixed to its surface. Each metal symbol was coated in ink and arranged to create specific words and sentences before being firmly pressed into paper. Chinese wooden block printing pre-dated Gutenberg's creation by around 600 years, but his was the first mechanised production method for the quick and cheap mass-production of texts.

The printing press could be used to produce 250 sheets of text per hour, superseding block printing and ending painstaking replication by hand. Texts were rapidly circulated throughout Europe and were made accessible to sections of the population other than royalty and the elite for the first time.

Revolutionary
The printing press enabled information to reach a wide audience quickly and cheaply and encouraged the spread of literacy.

Screw
To lower the plate onto the paper (or raise it up) a vertical screw was turned.



Inky impression
Enclosed in a holder, the paper was placed on a type form and slid under the plate.

The Antikythera mechanism

An ancient scientific device that accurately calculated the locations of stars and planets

80 The Antikythera mechanism was the most advanced astronomical instrument of the ancient era. Assembled by the ancient Greeks, or perhaps the Babylonians, it was lost for 2,000 years before being uncovered from a shipwreck off the Greek island of Antikythera in 1901.

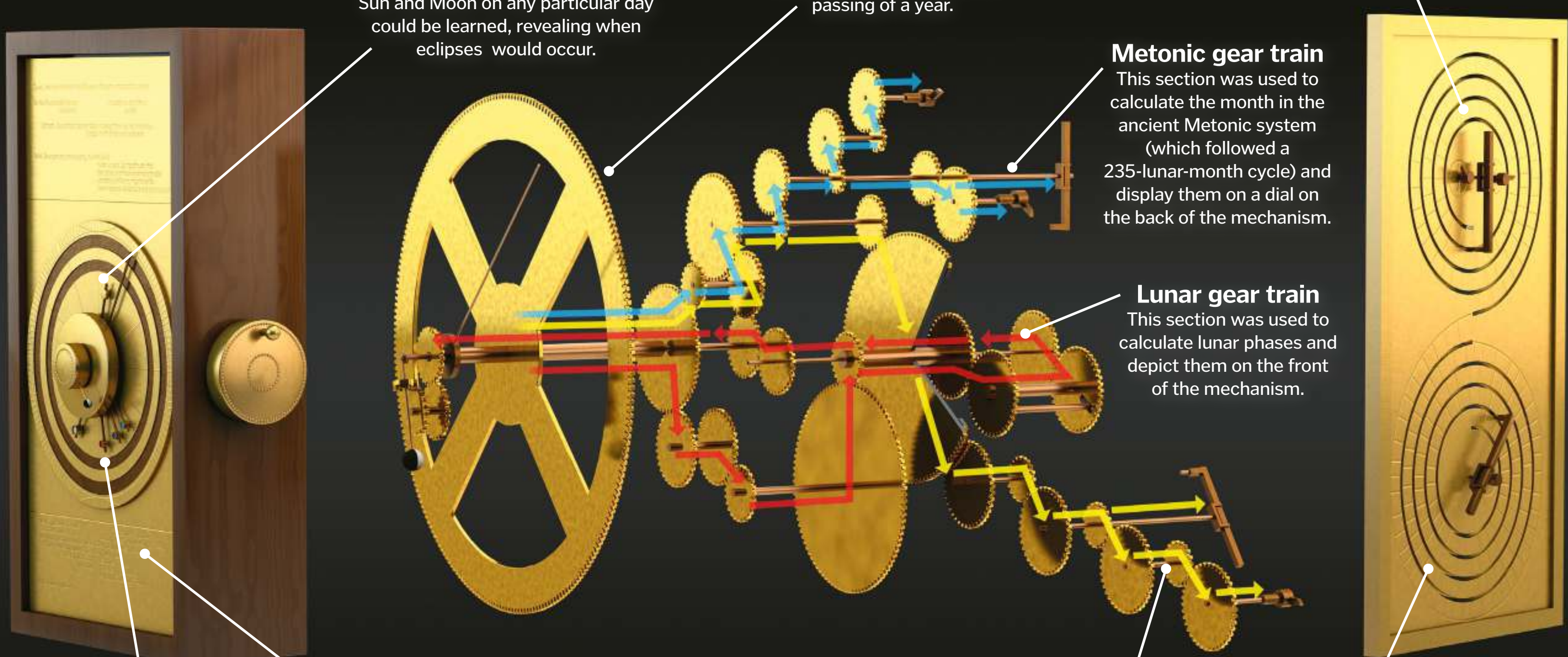
After meticulous study, scientists and historians declared the distorted mass of bronze to be an analogue computer, able to determine the positions of planets and the timing of eclipses. It accurately displays the phases of the Moon as well as the location of the five known planets in antiquity (Mercury, Venus, Mars, Jupiter and Saturn) in the sky.

Initially contained in a wooden case, only around 40 per cent of the original remains survive, and it is too delicate to examine by hand, so X-ray imaging and CT scans have been used to reveal how it worked. Inside, interlinking bronze gears are precisely arranged and cut exactly to size to turn rotating dials and pointers. The mechanism is evidence of the Greek's impressive astronomical knowledge and dates back to 205 BCE, the earliest date listed in the inscriptions on the device. It's the first invention we know of designed to show the layout of all the known celestial bodies in the sky at any given time, and was likely used for both educational and scientific purposes.

The 82 remaining fragments are kept at the National Archaeological Museum in Athens, Greece

How it could have worked

Based on the gears discovered, scientists can predict the mechansm's inner workings



Fossils

Discover life forms that lived millions or billions of years ago before being turned to stone

81 Extinction is a fact of life that, sooner or later, spells the end for all species. But dead doesn't mean forgotten. The evidence might have remained hidden for millions or even billions of years but, in the fifth century BCE, Greek philosopher Xenophanes discovered the fossils of sea creatures and recognised what they were.

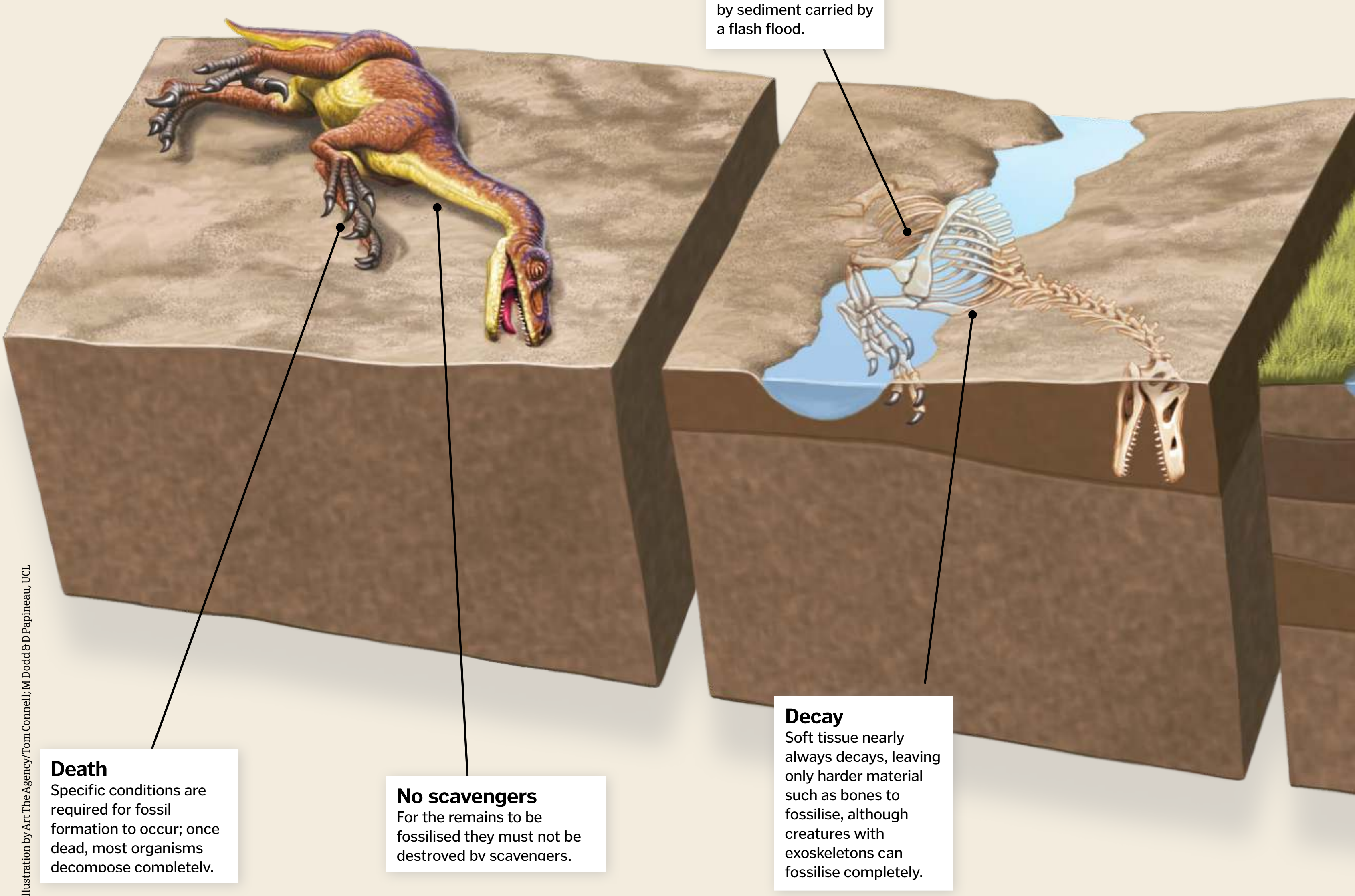
We'll look at exactly how it happens later, but put simply, a fossil was a living organism, which, following its death, turned to stone. And these records can teach us so much. Having found marine fossils on land, for example, Xenophanes was able to say with confidence that the sea once covered what was then dry land. Over the years, fossils have taught us a great deal about Earth's history, and the discoveries continue today.

For example, recent discoveries of fossils dating back to the dawn of our planet, when the Earth was an apparently inhospitable place, have fuelled speculation that life could have started on Mars at about the same time.

Mention fossils and many people think instantly of dinosaurs. These huge lizards might have left some of the largest, most impressive fossils, but they are not nearly the oldest, nor do they have a monopoly on providing a spectacle. The world of fossils is a varied one encompassing wonders as extraordinary as trilobites: large woodlouse-like creatures that crawled on the bed of tropical seas; brightly coloured petrified wood from long lost forests in Arizona; and coprolite – fossilised droppings.

The formation of fossils

How a living organism can be turned into stone and preserved for millions of years



Burial
Protection of the remains is assisted by rapid burial, perhaps by sediment carried by a flash flood.

Death
Specific conditions are required for fossil formation to occur; once dead, most organisms decompose completely.

No scavengers
For the remains to be fossilised they must not be destroyed by scavengers.

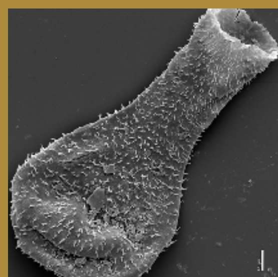
Decay
Soft tissue nearly always decays, leaving only harder material such as bones to fossilise, although creatures with exoskeletons can fossilise completely.

Top five fossil discoveries

The oldest fossils
Scientists at UCL have announced the oldest fossils yet. The tube-like structures, found in Canada, are about 3.77 billion years old and grew around deep-sea vents.

The largest fossil
Fossilised bones from Argentina represent the largest known dinosaur. The titanosaur was nearly 40 metres long, stood 20 metres tall, and weighed about 70 tons.

The smallest fossils
Not all fossils are massive; some are so small you need a microscope to see them. Marine microfossils known as Chitinozoa, for example, can be as little as 0.05mm long.

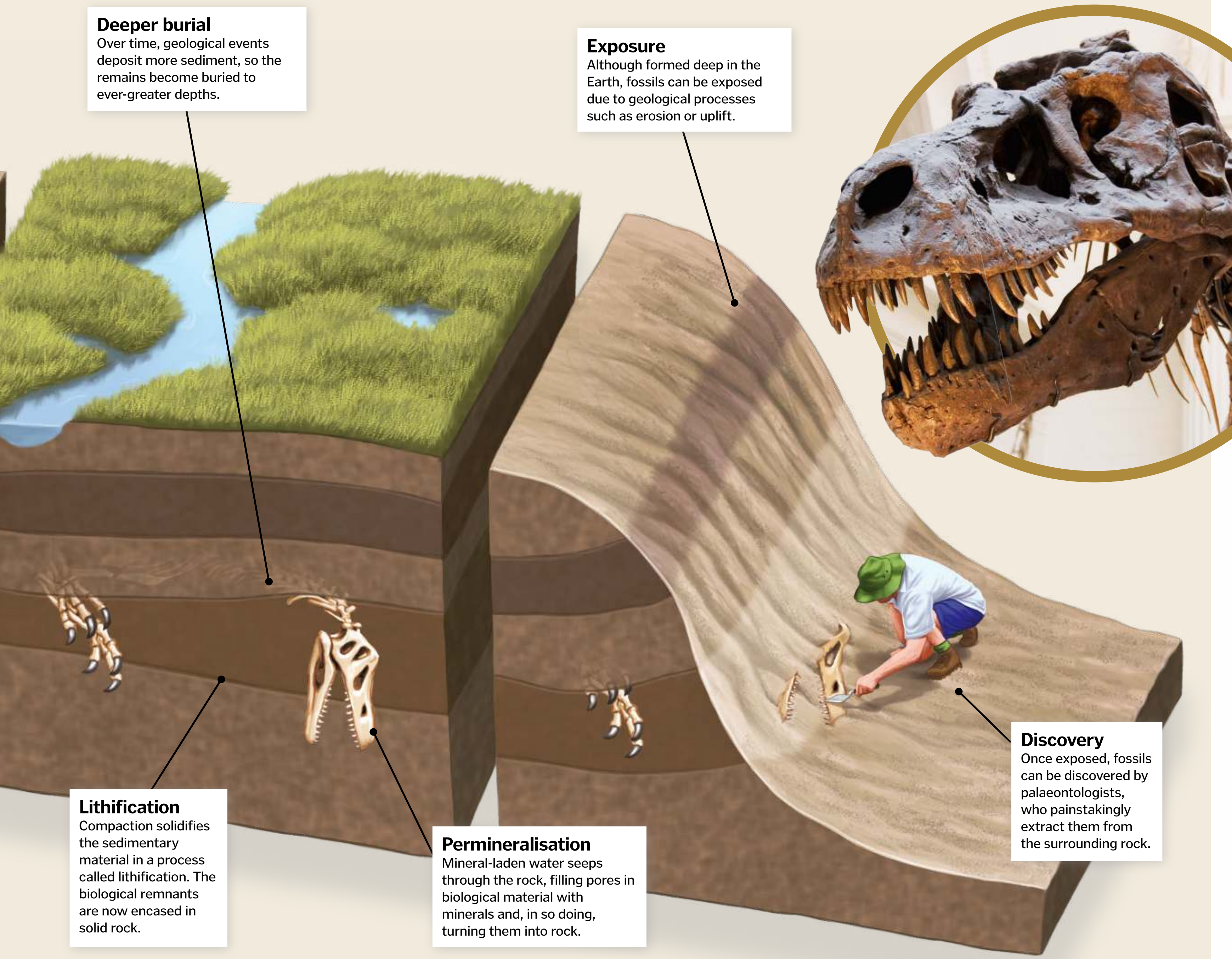


The rarest fossils
Soft tissue usually decays before fossilising, so fossils of creatures with no hard parts are rare. However, researchers at Berlin Free University recently found octopus fossils.

The family tree
Hominin fossils, such as the famous Lucy specimen, have enabled scientists to study human evolution. These findings have helped to shed light on our ancient cousins.

Deeper burial
Over time, geological events deposit more sediment, so the remains become buried to ever-greater depths.

Exposure
Although formed deep in the Earth, fossils can be exposed due to geological processes such as erosion or uplift.



Lithification
Compaction solidifies the sedimentary material in a process called lithification. The biological remnants are now encased in solid rock.

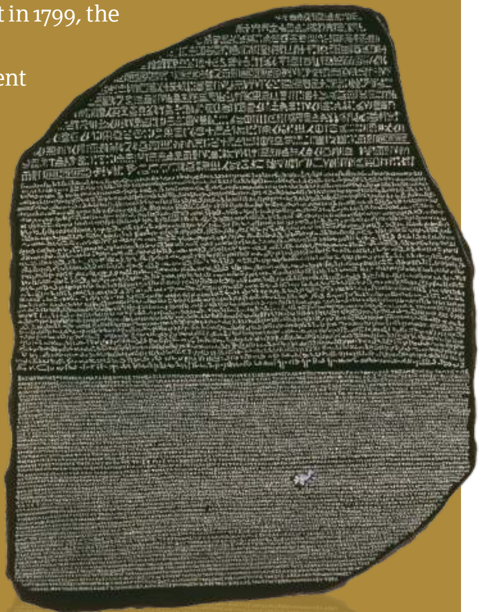
Permineralisation
Mineral-laden water seeps through the rock, filling pores in biological material with minerals and, in so doing, turning them into rock.

Discovery
Once exposed, fossils can be discovered by palaeontologists, who painstakingly extract them from the surrounding rock.

The Rosetta Stone

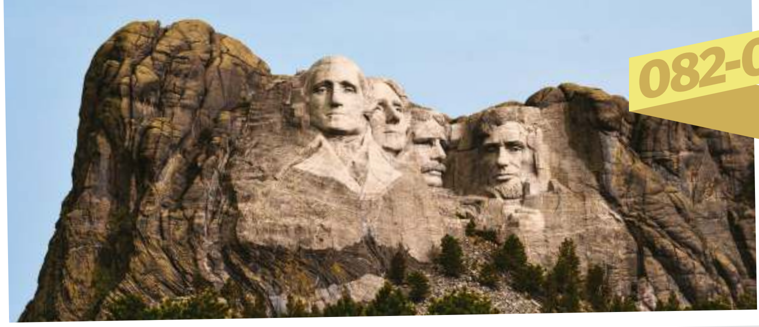
An invaluable artefact that unlocked the secrets of the ancient Egyptian language

82



Rediscovered in what is now Rashid, Egypt in 1799, the Rosetta Stone enabled ancient Egyptian hieroglyphics to be read for the first time in centuries. Its text, known as the Memphis decree, contains the same information in three different scripts: hieroglyphics, everyday ancient Egyptian (demotic) and ancient Greek. The text was fully decoded by scholar Jean-François Champollion in 1822 by comparing the hieroglyphs to the Greek, which was already understood. The discovery contributed massively to Egyptology.

"The Stone enabled ancient hieroglyphics to be read"



Mt Rushmore by numbers

83

Carved straight into the mountainside, this imposing monument immortalises four US presidents who had a huge influence on the republic in its first 130 years. From left to right, George Washington, Thomas Jefferson, Theodore Roosevelt and Abraham Lincoln symbolise the nation's founding, expansion, development and preservation respectively.

IT TOOK 14 years TO BUILD

The project began in 1927 but faced several delays

18m

The height of the monument

90%

TNT

of the monument was carved with dynamite. The rest was removed with drills and by hand

0 fatalities

Despite the risks involved, not a single person died during construction

84

Fire starters

The secret of fire made us who we are today

Technology triad

Three key advances set humans on the path to dominance: fire, hard tools and language. Flames kept us warm, allowed us to cook, and led to technological advancement.

Nutrient boosting

Feeding flames with grass and dung allowed us to keep fires going for cooking. Softer meals led to smaller teeth, and more calories allowed us to develop bigger brains.

Fire foraging

Before we mastered making fire, early humans may have chased natural blazes to find the treasures that they left behind, including cooked eggs, small animals and roots.

Handled weapons

Fire allowed us to attach solid tools to wooden handles. The pieces could be glued together with pitch and gypsum, made in the heat of the flames.

Fire drill

Prehistoric fires were started with fire drills (a stick twisted against a hearth to generate friction) or with flints (struck against metal to create sparks).

The International Space Station

Eight out-of-this-world facts about this amazing orbiting laboratory and how it has changed our planet for the better

85

7.7km

At an average orbital speed of 27,700km/h, this is how far the ISS travels each second

86

During its time in orbit, the ISS has travelled the equivalent of more than 40 round trips to Mars

87

6,000

Number of days (and counting) the ISS has been manned

It was assembled in space

Each section of the ISS was launched separately and put together in orbit

88 The first parts of the ISS, the Russian Zarya module and the US Unity module, were launched in 1998. Since then, more than 40 launches have been needed to assemble the ISS.

The majority of the ISS was transported to space by NASA's Space Shuttles. Each room, or module, of the space station was built on the ground. These sections were then launched aboard the Space Shuttles, which then slowly attached them to the ISS using its robotic arm. One exception to this were some of the Russian modules, which launched and flew independently to the station.

Astronauts Robert Curbeam and Christer Fuglesang work to attach a new ISS segment in 2006

Life support systems

The ISS is almost entirely self-sustainable thanks to some amazing technology

89

Keeping the astronauts alive on the ISS is no mean feat. Thankfully, the Environmental Control and Life Support System (ECLSS) helps to keep things ticking over.

The ECLSS is not one single unit, but instead a combination of the various components on the ISS that provide clean water and air to the astronauts. To generate oxygen, water is split into oxygen and hydrogen via the electrolysis of water in the Oxygen Generation System. Visiting spacecraft also bring tanks of oxygen as a backup supply.

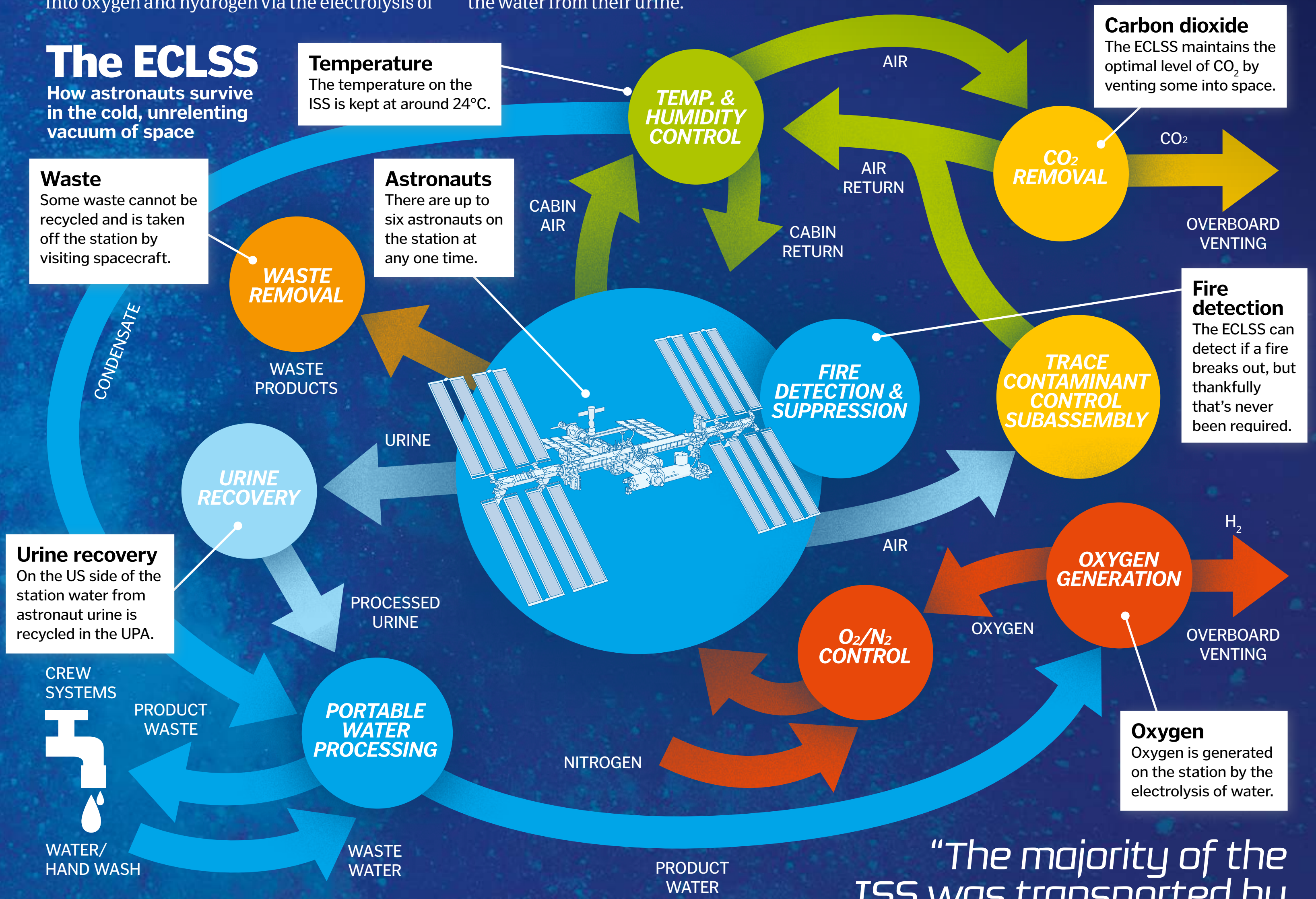
Around two-thirds of the water on the station is recycled via the Water Recovery System. On the US side this includes reusing water both in the atmosphere of the station and also in the waste of the astronauts via the Urine Processor Assembly. On the Russian side, they don't reuse the water from their urine.

The ECLSS also removes carbon dioxide from the air and keeps the levels of nitrogen, oxygen and other gases at a breathable level. It's also responsible for maintaining the temperature throughout the station and moving air between the modules.

Put simply, the ECLSS is vital to life on the ISS, and lessons learned from it will no doubt be essential for future space exploration missions.

The ECLSS

How astronauts survive in the cold, unrelenting vacuum of space



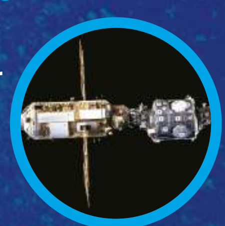
"The majority of the ISS was transported by NASA's Space Shuttles"

Building the ISS

How the space station has evolved over the past two decades

November 1998
Module: Zarya
This initially provided power and propulsion, but is now used for storage.

December 1998
Unity
This acts as a connecting node for the station.



July 2000
Zvezda
This section provides the station's vital life support systems.

February 2001
Destiny
The main research module used by the US astronauts.

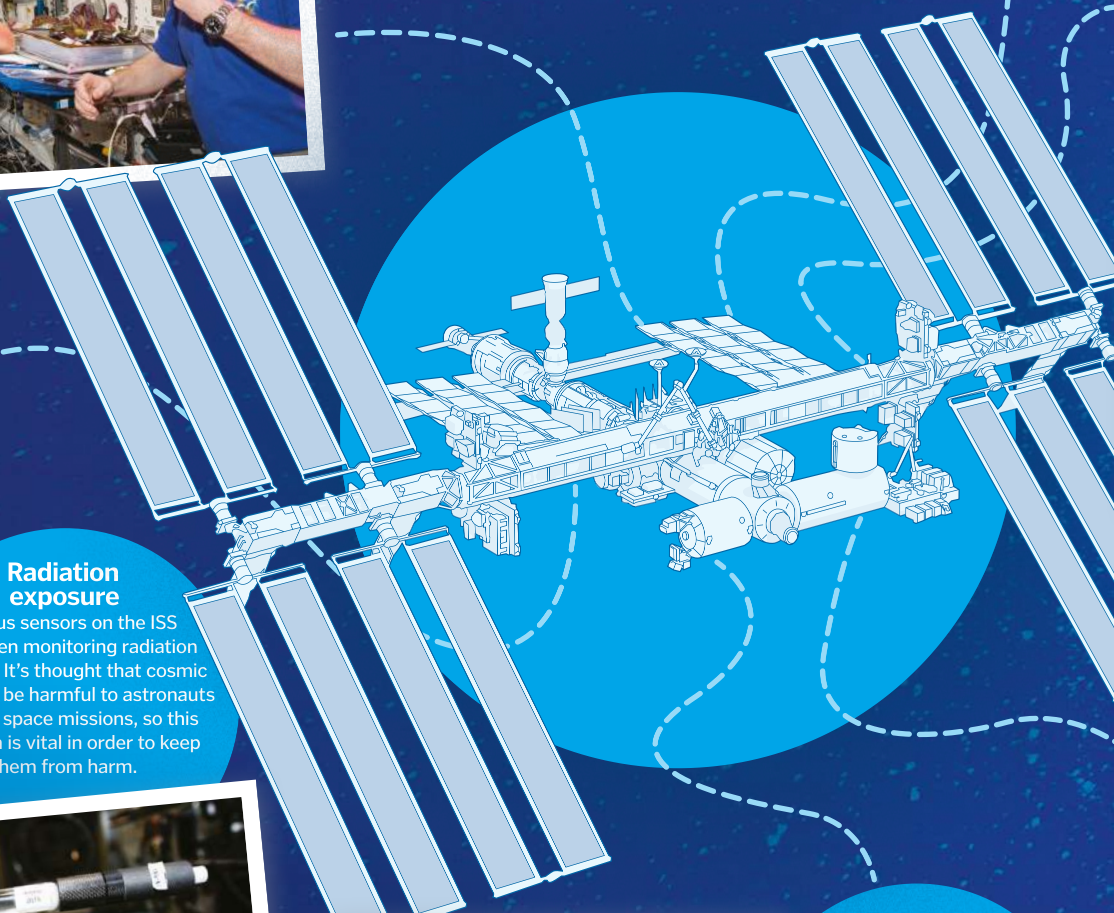
90

A testbed for space exploration

What we learn on the ISS could one day help us travel to Mars and beyond

Growing food
If we're going to survive on another planet we might need to grow our own food. The ISS has been used to grow a variety of plants, including rice and lettuce, to test how we might do this elsewhere.

3D printing
Made In Space's 3D printer has been operational on the ISS since 2014. So far it has mostly been used for basic experiments, but in the future we may rely on this technology to build tools and components on other worlds.

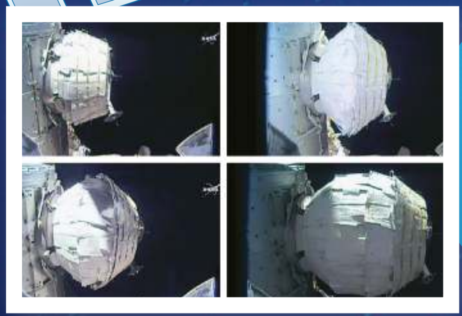


Long duration spaceflight
Most astronauts stay on the ISS for six months, but from March 2015 to March 2016 astronaut Scott Kelly and cosmonaut Mikhail Kornienko spent one year on the ISS to help practise for the long duration missions needed to get to Mars.

Radiation exposure
Various sensors on the ISS have been monitoring radiation for years. It's thought that cosmic rays could be harmful to astronauts on deep space missions, so this research is vital in order to keep them from harm.

Private space exploration
The ISS has helped usher in an age of private space exploration. It has welcomed vehicles and equipment from SpaceX, Orbital ATK, and more. These companies may one day form part of an extensive infrastructure in Earth orbit as NASA heads for Mars.

Inflatable technology
In April 2016, the Bigelow Expandable Aerospace Module (BEAM) was attached to the ISS. It was pumped full of air in May 2016 to expand to five times its previous volume. This could be used on future spacecraft to save on space at launch.

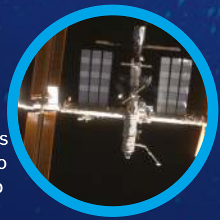


"Plants including rice and lettuce have been grown onboard the ISS"

April 2001
Canadarm2
This can grab and move spacecraft and other objects.

2002-2007
Truss
The process of assembling the supporting structure of the ISS begins.

October 2007
Harmony
Sleeping quarters for the crew. Two others can sleep in Zvezda.



February 2008
Columbus
The ESA's research laboratory on the ISS.

Impossible experiments

Research not possible on Earth has taken place on the ISS

91 Astronauts perform hundreds of experiments during their time on the station. The microgravity environment of the ISS allows for some fascinating research that is simply not possible on Earth. Ranging from biology to chemistry, the station has become a hotbed of groundbreaking experiments.

One example is protein crystal growth, where astronauts have developed high quality protein crystals on the ISS. It's hoped that this research could be useful in developing drugs to combat many diseases including Alzheimer's and muscular dystrophy.

From the Japanese Kibo module, astronauts are able to launch cubesats into space; small satellites the size of a loaf of bread developed by students and organisations on Earth. These provide a new way for researchers to study Earth and its atmosphere.

Astronauts have also helped to advance laser eye surgery by wearing an eye tracking device. This enabled scientists on Earth to see how the eye's position changes, essential for the precise movements needed in laser surgery. There have also been studies to find out how astronauts can stay healthy during long spaceflights. By exercising regularly, astronauts can reduce the level of bone mass loss they experience. These findings may also help treat osteoporosis sufferers back home.

More recently, a sample of the superbug methicillin-resistant *staphylococcus aureus*, or MRSA, was taken to the ISS early in 2017. Scientists hope to see how it evolves and help combat its rapid mutations here on Earth.

Experiments like this provide an insight into the motion of liquid in microgravity

Astronauts of all walks of life have worked together on the ISS

International cooperation

The ISS is one of the greatest global collaborations in history

92 More than 16 countries have been involved in the assembly and operation of the ISS. The two major players are the US and Russia, and their commitment to work together in the 1990s on the station was seen as a major breakthrough in relations.

Since then, countries including Canada, the UK, Italy, Japan and more have all been involved in one way or another. Astronauts from a variety of countries have flown to the station, and people around the world are able to see it in the night sky as it flies overhead. The ISS is a testament to what can be achieved when countries decide to work together. It's likely that for future missions to Mars or elsewhere, similar cooperation will be essential and welcomed.

March 2008
Kibo
Japan's research module on the ISS.

February 2010
Cupola
The large windows afford glorious views of Earth.

May 2011
AMS
Experiment module to hunt for dark matter in the universe.

April 2016
BEAM
The latest arrival: an inflatable room to test how to expand modules in space.

Buzz Aldrin (pictured) and Neil Armstrong spent 21 hours on the lunar surface during Apollo 11

93

The Apollo Program

The trailblazing NASA missions that took us to the Moon

In the late 1950s, the US and the Soviet Union were racing to reach a major milestone in spaceflight: put humans on the Moon then return them safely back to Earth. In July 1969, NASA launched Apollo 11, carrying astronauts Neil Armstrong, Buzz Aldrin and Michael Collins. Armstrong's famous words, broadcast from the lunar surface, clinched the title for the Americans and changed the course of human history: "One small step for a man, one giant leap for mankind."

NASA was formed in 1958 and the Apollo Program was only its third major spaceflight initiative. In order to achieve this ambitious goal, it designed and built a whole new breed of vehicles. The Saturn V rocket, which eventually launched all six manned lunar landings, was taller than the Statue of Liberty and weighed as much as 400 elephants. It was more powerful than any rocket that came before it.

The astronauts themselves rode in the Apollo spacecraft, a small portion at the top of the enormous launch vehicle. Once the rocket had put Apollo on course for the Moon it fell away, leaving the spacecraft to complete the four-day journey and return to Earth.

From 1969 to 1972, 12 astronauts walked on the Moon, some staying for as long as three days to conduct detailed surveys and experiments on their surroundings. Over the six missions, almost 400 kilograms of lunar samples were collected and brought back to Earth. The astronauts also installed six observatories on the surface of the Moon, which operated for many years after the surface was free of human footsteps. The wealth of data has not only transformed our understanding of the Moon but also hinted at the history of Earth and the entire Solar System.

"Saturn V was more powerful than any rocket that came before it"

Saturn V launched Apollo 15 from NASA's Kennedy Space Center in Florida

Lunar rovers enabled the Apollo 15, 16 and 17 astronauts to explore much larger areas

Apollo discoveries

The Moon is lifeless
No signs of life, past or present, were found in the lunar samples collected during the Apollo missions.

The Moon is asymmetrical
The Moon's crust is thicker on the far side, while most of its volcanic basins lie on the near side.

The young Moon melted
Early in its history, the Moon was heated to create a molten ocean of magma, topped with a rocky crust.

Asteroids shaped the Moon
The large, dark basins on the Moon were created by huge asteroid impacts, which were later filled by flowing lava.

Moon rubble tells a story
The Moon is covered in rubble that contains clues to the Sun's activities over the last 4 billion years.

Apollo missions
A history of NASA's lunar exploration

Apollo 1
- Never launched
- Manned
- Test flight, destroyed during pre-flight test

Apollo 2 (re-designated)
- 25 August 1966
- Unmanned
- Test flight, success

Apollo 3 (re-designated)
- 5 July 1966
- Unmanned
- Test flight, success

Apollo 4
- 9 November 1967
- Unmanned
- Test flight, success

Apollo 5
- 22 January 1968
- Unmanned
- Test flight, success

Apollo 6
- 4 April 1968
- Unmanned
- Test flight, engine failures

Apollo 7
- 11 October 1968
- Manned
- Earth orbit, success

Apollo 8
- 21 December 1968
- Manned
- Lunar orbit, success

Apollo 9
- 3 March 1969
- Manned
- Earth orbit, success

Apollo 10
- 18 May 1969
- Manned
- Lunar orbit, success

Apollo 11
- 16 July 1969
- Manned
- Lunar landing, success

Apollo 12
- 14 November 1969
- Manned
- Lunar landing, success

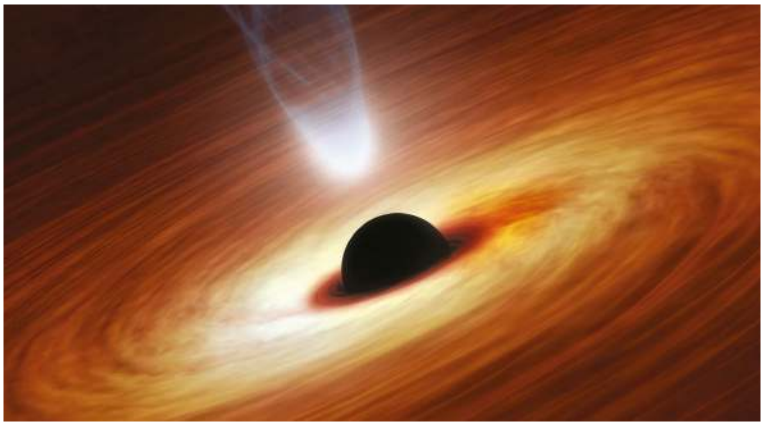
Apollo 13
- 11 April 1970
- Manned
- Lunar landing, aborted on outward flight

Apollo 14
- 31 January 1971
- Manned
- Lunar landing, success

Apollo 15
- 26 July 1971
- Manned
- Lunar exploration, success

Apollo 16
- 16 April 1972
- Manned
- Lunar exploration, success

Apollo 17
- 7 December 1972
- Manned
- Lunar exploration, success



Black holes

One of the universe's greatest phenomena, and we can't even see them

94 Black holes are objects of extreme gravity, where matter is squashed so tightly that its cores have singularities of extreme density. Around the centre, the gravitational pull is so strong nothing can escape – not even light.

At the centre of most galaxies is a supermassive black hole, a vast black hole billions of times more massive than our Sun. These dictate the movement and evolution of galaxies. But for all their wonder, we've still never seen a black hole directly.

Constellations

These groups of stars have helped us to map the night sky

95 Constellations are groups of stars in our galaxy that from Earth appear to make a particular pattern. While none have any actual scientific value, they are useful markers for exploring the night sky. Different constellations appear in the sky depending on the time of year and the direction each hemisphere of Earth is facing.

Today, we have mapped out 88 official constellations, which split the sky up into different segments. But while they look close together, often the stars within a constellation can be separated by hundreds or thousands of light years.

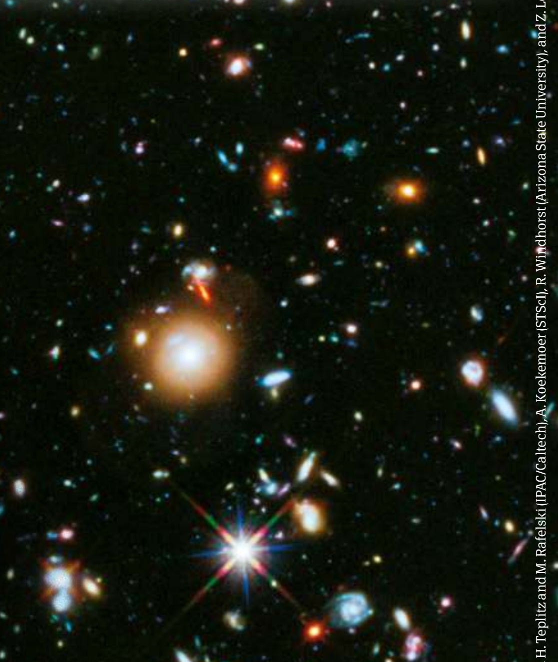
Hubble: seeing through time

How the Hubble telescope has helped us look back to the dawn of the cosmos

96 In 1995, the Hubble Space Telescope was pointed towards a seemingly barren part of the sky. For ten days it looked at this nondescript region in the constellation of Ursa Major, in which no telescope had seen much of note. Hubble, however, returned a fascinating series of images revealing not nothing at all but 3,000 galaxies stretching far back into the universe.

This is known as the Hubble Deep Field, and is one of Hubble's crowning achievements. By looking at regions of the skies with a long exposure, the telescope has been able to see some of the most distant and dimmest galaxies stretching back through the 13.8-billion-year history of the universe.

It has since been usurped by the Hubble Ultra-Deep Field in 2004, and the Hubble eXtreme Deep Field in 2012, which were each the deepest astronomical images ever seen at the time. Now, through a programme called Frontier Fields, Hubble is using the gravity of galaxy clusters to see even further back. These act as gravitational lenses, allowing it to look at the earliest galaxies of all, some dating just a few hundred millions years after the Big Bang.



The 2004 Hubble Ultra-Deep Field - updated in 2014 to include ultraviolet data - contains approximately 10,000 galaxies

Water in the Solar System

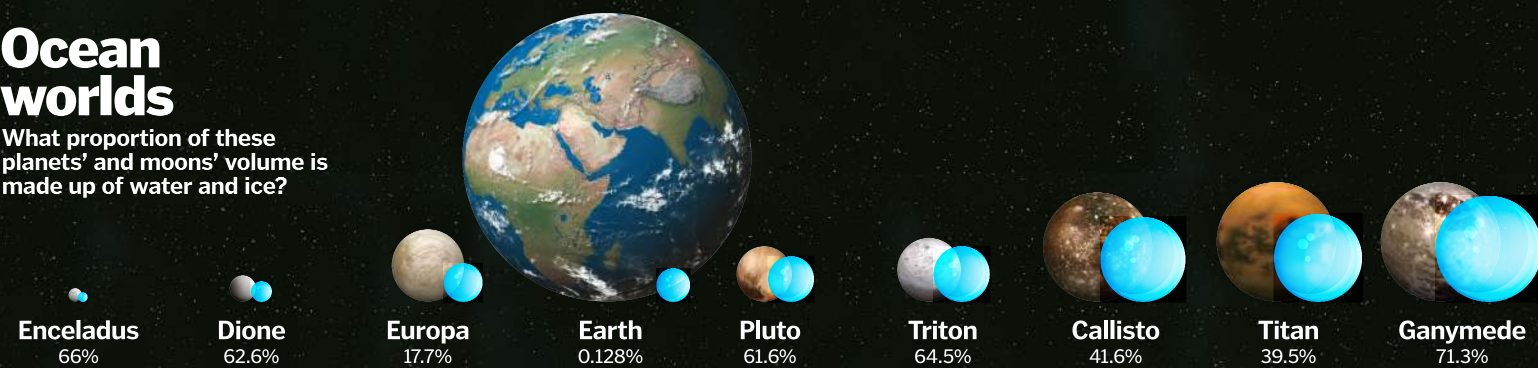
There are a surprising number of wet planets and moons in our cosmic neighbourhood

97

Earth is the only place in our Solar System with visible bodies of liquid water on its surface. But surprisingly, it is not the only place with water. We now know that many planets and moons have water in one form or another. Venus has some water vapour in its atmosphere, possibly left over from former oceans. Mars has trickles of water on its surface, and may have large amounts of ice underneath it. And moons including Europa and Enceladus are thought to have vast oceans under their icy surfaces, which have revealed themselves via great plumes of water ejected into space.

Ocean worlds

What proportion of these planets' and moons' volume is made up of water and ice?

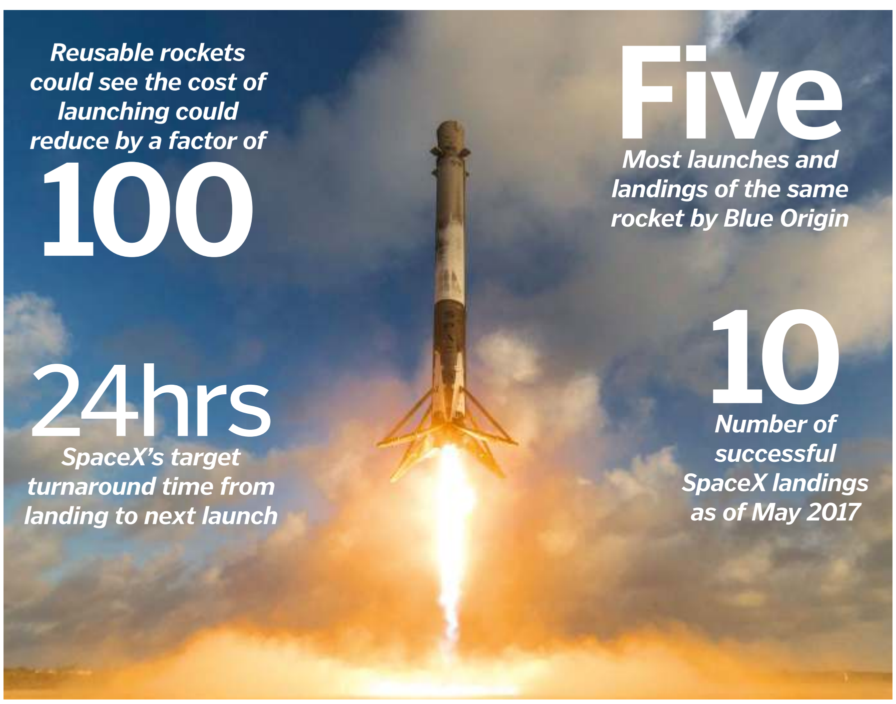


Reusable rockets

The future of space travel may depend on rockets tha can fly again and again

98

Imagine every time you took a flight somewhere, your plane was scrapped after it landed. Sounds wasteful, but that's the case for most space launches at the moment. Fortunately, companies like SpaceX and Blue Origin are working to change this, and they have been successful in launching, landing and reusing their rockets. If the technology is perfected, the cost of going to space could dramatically decrease in the future.



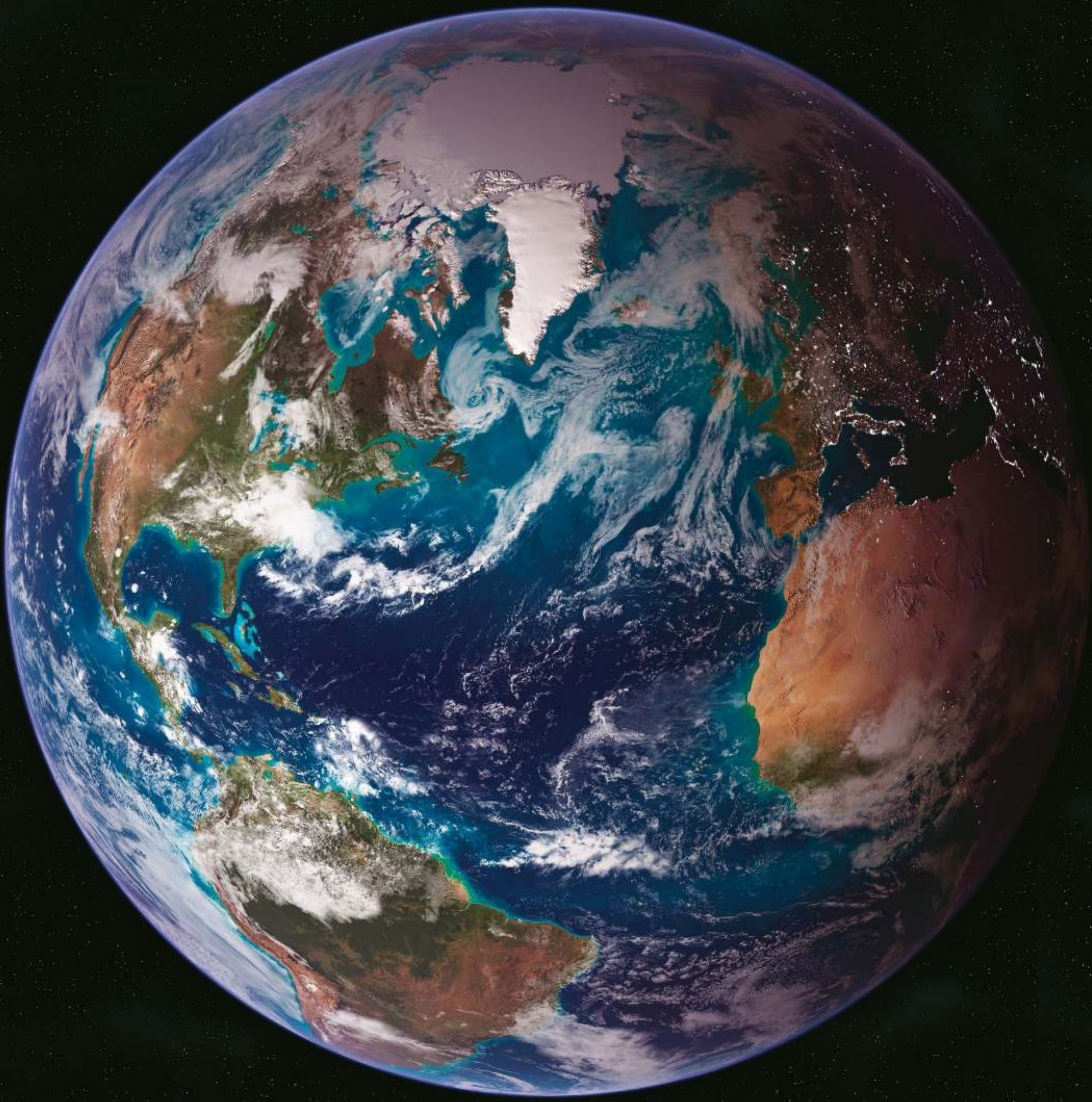
Nebulae

These huge clouds of cosmic gas and dust can form stars and planets

99

Nebulae can span millions of light years, appearing as glorious shapes when we look at them from a distance. Over time, gravity can pull parts of them together into new stars and planets. Some nebulae are the result of stars exploding as a supernova, leaving behind these vast clouds of debris. Others are a combination of gas being pulled together in interstellar space, while some are regions where gas has cooled and condensed. But however they form, they are truly a sight to behold.

The Rosette Nebula contains enough gas and dust to form 10,000 Sun-like stars



The blue marble

Thanks to our perfect home, we've been able to experience every other wonder

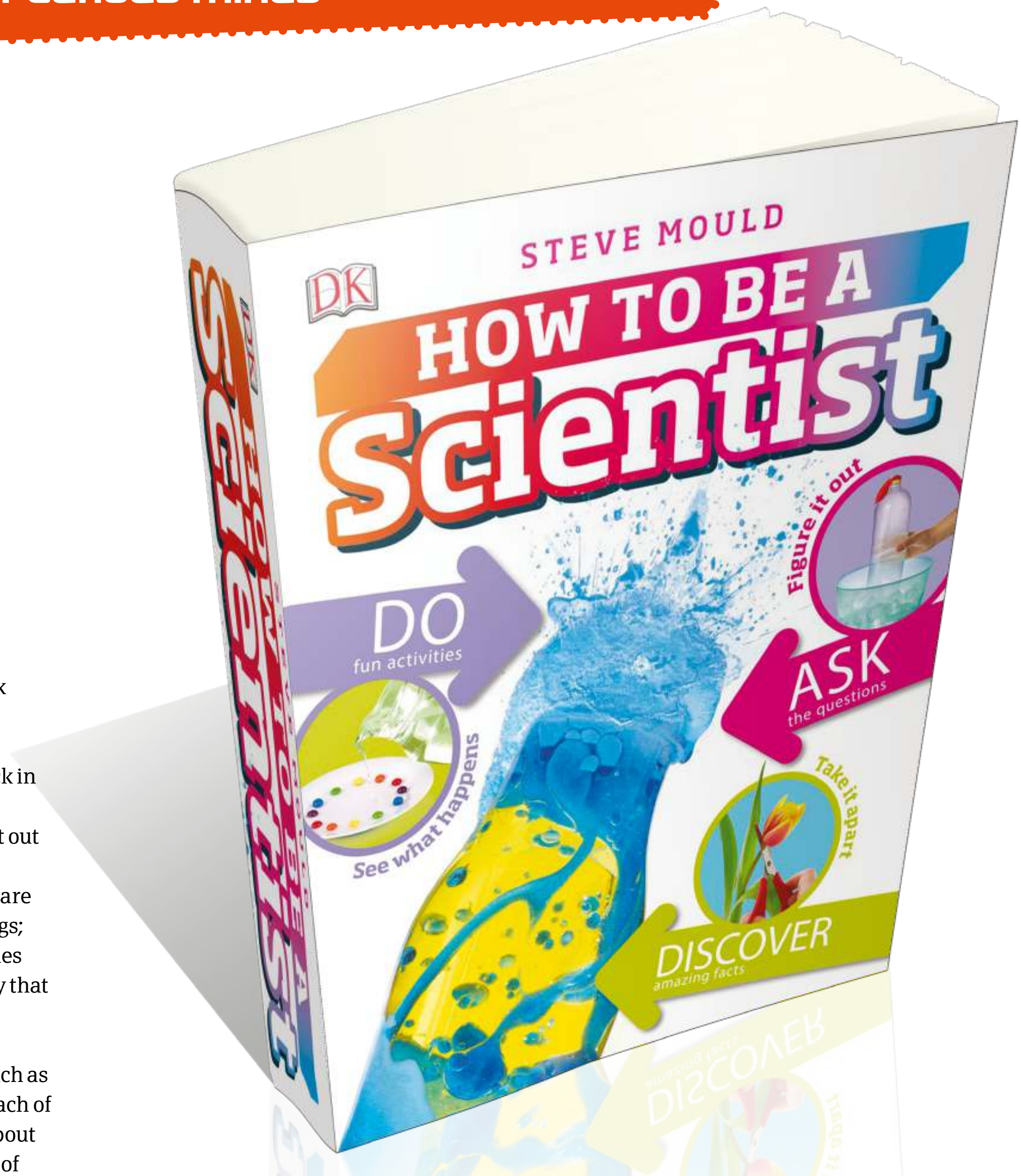
100 Just a few hundred years ago, most people believed our planet was placed at the very centre of the universe. However, through advancements in astronomy we soon found this not to be true, and instead discovered that we are but a tiny speck within the huge expanse of the cosmos. Our home galaxy, the Milky Way, is home to an estimated 100 billion planets, itself one of 2 trillion galaxies in the universe. But we still have every reason to feel special, because we've yet to find a planet as ideal for life as ours.

When our planet formed from a swirling ring of gas and dust 4.5 billion years ago, it contained the raw ingredients it would need to transform into an abundant oasis of life. Its distance from the Sun allowed for water to eventually exist in liquid form across the globe, and underneath the surface, its active mantle led to energy-producing volcanoes that would power the first life forms on Earth. These organisms would divide and evolve in a soup of chemical ingredients integral to life, and billions of years later, the first species would venture onto our planet's surface. Here they would be protected from the Sun's harsh radiation by a thick atmosphere – held in place by the magnetism generated within our Earth's molten iron core – and they would be able to thrive.

Today, over 8 million species live on Earth. Throughout humanity's brief time here, it's played host to every war and every conquest, to every idea and every discovery. And although we now dream of venturing out into the cosmos, we may never find a home as bountiful, or as beautiful, as our blue marble.

BOOK REVIEWS

The latest releases for curious minds



How To Be A Scientist

A mix of practical science and fun facts

- Author: **Steve Mould**
- Publisher: **DK**
- Price: **£12.99 / $19.99**
- Release date: **Out now**

There are many science books that talk about important discoveries, major theories and famous scientists from history. There are also many books that pack in dozens, if not hundreds, of scientific experiments that you can try at home to test out scientific theories, before linking these experiments back to science. However, it's rare to find a book that combines these two things; *How To Be A Scientist* brings scientific theories and practical experiments together in a way that keeps you turning through the pages to see what's next.

The book is divided into six categories, such as Space, Chemistry and Natural World, and each of these categories has a mix of information about the topic and things to try yourself. In some of the more experiment-focused books, some of the tests require hard-to-find materials, or a great deal of preparation. *How To Be A Scientist* keeps things simpler; the experiments are only two or three steps long, use materials you will likely have at home, and don't take much time. Each one is linked back to a theory, so you will keep asking questions about what you've learned, which prolongs the fun.

Elsewhere, you'll find pages dedicated to important names in the scientific community, which explain what they did, when they lived and why their work was important. These are backed up by fun illustrations and other imagery to ensure younger readers stay entertained. The target age range here is around seven to 11 – older readers may find the text or experiments a little too simple.

Still, for those younger readers, the science here is sure to enthrall. Trying things like flipping drawings by placing them in glasses of water will amaze, while experiments surrounding solar energy and information about the water cycle will help children learn important lessons about the environment and the world around them. The simplistic nature of the language throughout the book, and of some of the experiments, might put off more advanced readers, but this is still an excellent way to get children reading, thinking and actively engaging in science.

★★★★☆

YOU MAY ALSO LIKE...

101 Great Science Experiments

Author: **Neil Ardley**
Publisher: **DK**
Price: **£7.99 / $9.99**
Release date: **Out now**

With over 100 experiments packed into this book, there will be plenty to keep kids interested. Some are quick, while others take longer and are more involved, but science is always the focus.

365 Science Activities

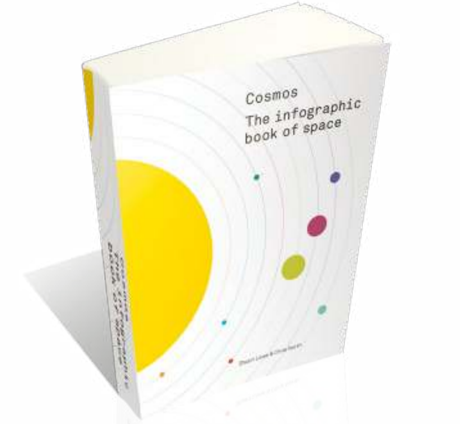
Author: **Minna Lacey**
Publisher: **Usborne**
Price: **£12.99 (approx. $17)**
Release date: **Out now**

Lovely photography and interesting experiments keep this book interesting throughout. It's designed with one experiment a day in mind, but you'll want to try them all right away.

George's Marvellous Experiments

Author: **Roald Dahl, Barry Hutchinson**
Publisher: **Puffin**
Price: **£7.99 (approx. $10)**
Release date: **Out now**

Inspired by Roald Dahl's famous book and featuring illustrations by Quentin Blake, this book includes easy-to-follow experiments using everyday objects.

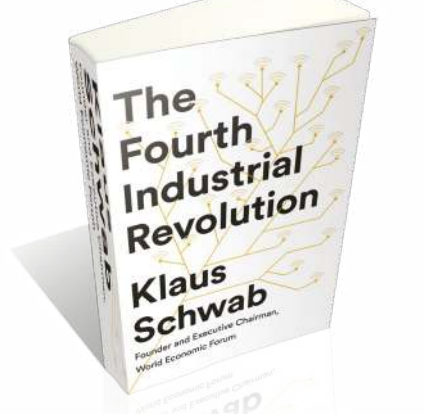


Cosmos: The Infographic Book Of Space

A fact-filled look at the wonders of the universe

- Author: **Dr Stuart Lowe and Dr Chris North**
- Publisher: **Aurum Press**
- Price: **£25 / $34.99**
- Release date: **Out now**

Completely captivating and visually impressive, this book is a terrific read for anyone fascinated by space. It's packed full of engaging infographics that visually explain a variety of topics, from space stations to the structure of galaxies and stars. The infographic medium is particularly effective at presenting information about scale, such as comparing the sizes of telescopes or asteroids. These visualisations provide an immediate sense of perspective. We enjoyed the accompanying website, too, which offers interactive versions of some of the graphics inside the book.



The Fourth Industrial Revolution

An insight into the future of technology

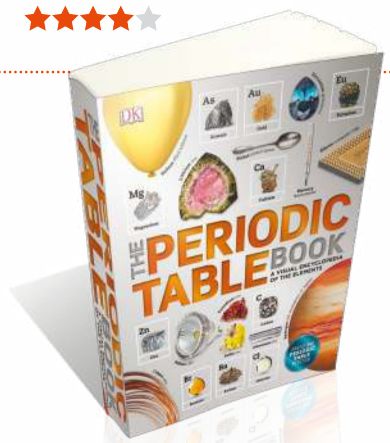
- Author: **Klaus Schwab**
- Publisher: **Penguin**
- Price: **£14.99 / $28**
- Release date: **Out now**

An array of new technology has put humanity on the verge of a new era. That's the message being put forward by Klaus Schwab's intriguing book, *The Fourth Industrial Revolution*. As the founder and executive chairman of the World Economic Forum, Schwab is perfectly placed to comment on the potential impact that the likes of 3D printed organs will have. Schwab's writing is pragmatic and optimistic as he reaches some intriguing conclusions. A few interviews with the innovative tech gurus that are contributing to this progress would have been a bonus, but nevertheless, this is a fascinating book.

The Periodic Table Book

All 118 chemical elements in one great book

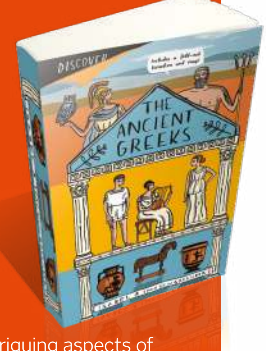
- Author: **Various**
- Publisher: **DK**
- Price: **£14.99 / $22.99**
- Release date: **Out now**



This bright and breezy introduction to all the chemical elements on the periodic table is a must for any young science lover. This encyclopedia is a visual tour of all known natural and human-made elements, from commonly known hydrogen and iron to newer elements like oganesson and nihonium. With over 1,000 colour photographs, *The Periodic Table Book* is superbly illustrated and a selection of interesting factoids will appeal to all audiences. For instance, who knew that niobium is used in the lenses of glasses as well as Apollo 15's command module? In essence, this is the perfect starting point for those wanting to learn about the building blocks of the universe.

Discover... The Ancient Greeks

History gets illustrated

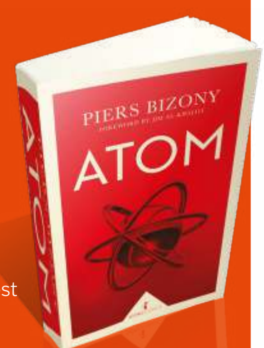


- Author: **Isabel & Imogen Greenberg**
- Publisher: **Frances Lincoln**
- Price: **£11.67 / $14.99**
- Release date: **Out now**

Having been big fans of *Horrible History* books growing up, we'll embrace anything that presents history in a fun and accessible style, which makes this latest offering from the *Discover...* range all the more welcome. Containing chapters on many of the most intriguing aspects of Greek history – from Alexander the Great and the Olympics to the Trojan War – the illustrated cover is immediately eye-catching, a theme that continues throughout the book. Accompanied by speech bubbles that talk you through everything, this is ideal for primary school pupils.

Atom

Positively charged

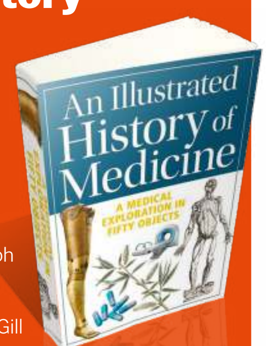


- Author: **Piers Bizony**
- Publisher: **Icon**
- Price: **£8.99 / $14.95**
- Release date: **Out now**

The story of the humble atom is a surprisingly tumultuous one. First given form by John Dalton in the early 1800s, it wasn't until the discoveries made by Ernest Rutherford nearly 100 years later that we first began to truly understand one of the building blocks of life itself. Inspired by the BBC series *Atom*, within these pages writer Piers Bizony charts not only a quest of discovery, but a travel through the modern history of science itself, with figures like Marie Curie, Albert Einstein and Robert Oppenheimer all getting page time. This is more than a who's who of science though – it's a truly special undertaking.

An Illustrated History Of Medicine

Just what the doctor ordered



- Author: **Gill Paul**
- Publisher: **Quad Books**
- Price: **£9.99 (approx. $13)**
- Release date: **Out now**

What do Neolithic trepanned skulls, Joseph Lister's donkey engine and Crick and Watson's double helix have in common? They're all contained within the pages of Gill Paul's *An Illustrated History Of Medicine*. In truth, this description just scratches the surface, with 47 other topics completing this journey through medicine and its evolution. Presenting a nigh-on perfect melding of information and attention to detail, to say this was exactly what we expected is in no way a bad thing. It's not a comprehensive history, but it's certainly useful for finding subjects to dive into deeper.

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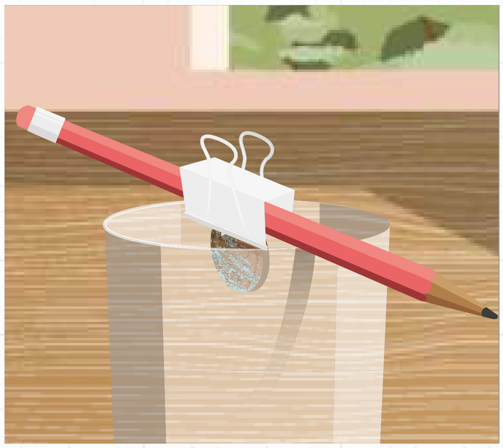
How to clean dirty coins

Remove the oxide layer from the outside of dirty coins using fruit juice!

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU


1 Find some coins

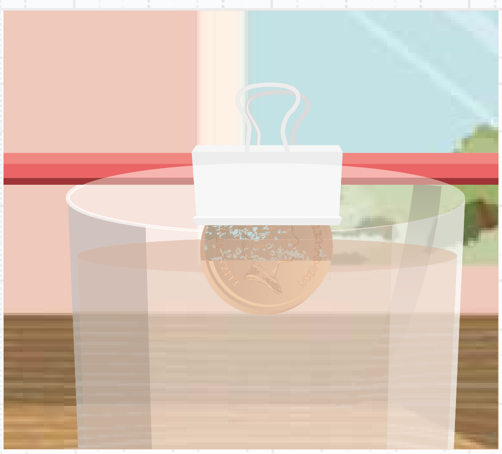
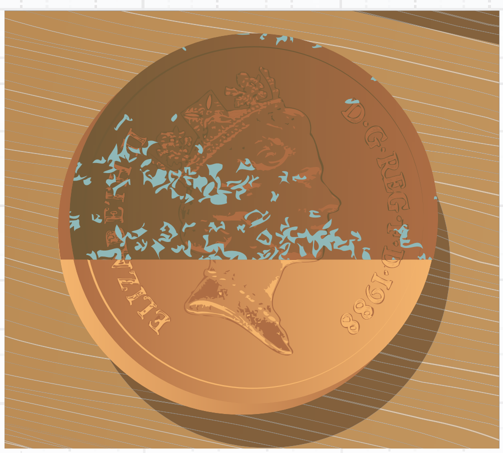
First, you'll need to find some coins to clean. Newer coins will already be very clean, so you're looking for older ones if possible. Coppers like pennies or 2p pieces are best for this, but you can use silver coins if necessary. Try to find coins that are really dirty or even a little bit tarnished so that you will be able to really see the difference cleaning can make.

2 Clip them on

We're only going to submerge half of the coin – the other half will not touch the liquid. This means the weak acids in the cleaning liquid will not affect the other half, so you'll be able to see the difference. You need a strong clip to secure the coins above the glass, so use a bulldog clip to hold the coin and push a pencil through the top to balance your clip across a glass.

3 Prepare your cleaner

You might be surprised to hear that the cleaning liquid we're going to use is actually apple juice. The juice contains citric acid, a weak acid that can help to clean coins. The coin is dull because the copper in the metal has reacted with oxygen in the air to form copper oxide. This oxide makes the coin look dirty, but the citric acid in the juice will get rid of it and restore the coin's shine.

4 The waiting game

You need to pour the fruit juice into the glass so that it only covers the bottom half of the coin. Don't worry if you happen to put too much in – just pour a little bit out of the glass until the level is right. You now need to leave the coin in the fruit juice for at least a few hours – if possible, leave it overnight for the best results. Then remove the coin to see how effective the cleaner is!

5 Other cleaners

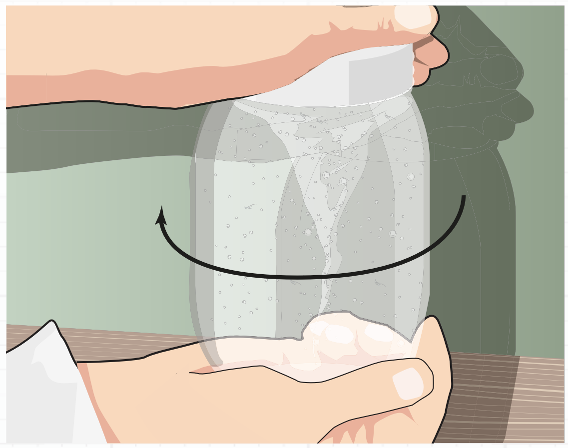
You can use other liquids to clean your coins, too. Different fruit juices contain different levels of acid, so experiment with a variety of options to find which is the most effective. You can also try liquids like ketchup, which contains vinegar, or just vinegar on its own. Vinegar contains acetic acid, which is quite strong, so it should do a great job of cleaning your coins.

"Coppers like pennies or 2p pieces are best, but you can use silver coins if necessary"

In summary...
When metals react with oxygen in water or air, they form oxides. These oxides are often referred to as 'rust'. Weak acids can dissolve metal oxides, allowing you to restore the shine of coins. However, doing so will remove a very thin outer layer of the coin, so if you did it too much you wouldn't have a coin left!

Make a tornado in a jar

Create a swirling tornado of bubbles at home



1 Make your solution
First, take an empty jam jar and fill it with water. Top it up with a little washing-up liquid and then seal the jar tightly to stop the water from escaping. Now you'll need to shake the jar hard to form a layer of bubbles at the top of the jar. When you create your tornado, these bubbles will be what you see forming the 'cone' of the tornado itself in the centre of your jar.

2 Spin it!
Place the bottom of the jar on the palm of one hand and grip it tightly, then put the other hand on top of the lid. You need to start moving the jar in circular motions, so begin moving both hands in circles, starting slow and speeding up. The aim is to get the liquid in the jar to start spinning and swirling around the edges, so keep the circular motions quite small to get it going.

"These bubbles will be what you see forming the tornado 'cone'"

In summary…
The water in the jar is forced outwards as you rotate the jar. However, when it hits the glass, it can't get out, so starts moving in a circular motion. Gravity pulls more water to the bottom of the jar, but the outward force means that some is pushed up the sides, and the bubbles descend into the middle of the jar.

3 Take a look
Place the jar straight down onto a flat surface and take a look at the results. You should see a cone of bubbles, with the thin end touching the bottom of the jar and the wider end spinning near the lid. As time goes by, watch how the cone starts to reduce in size and the bubbles start moving towards the top of the jar. This happens because the water slows down and eventually stops spinning.

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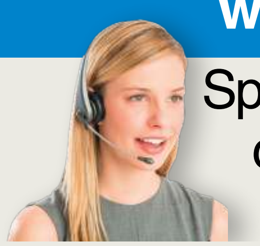

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ISSUE 200

Here's what the HIW team think you'll read about in 2025

JAMES

"Icy moons like Europa and Enceladus look like our best bets for finding alien life. Hopefully our space probes will have found some evidence by 2025!"

DUNCAN

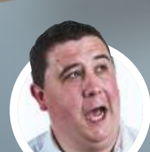
"With new inventions like the Sabre engine, I think hypersonic travel will become the norm by 2025. A four-hour flight from London to Sydney is already in the pipeline!"

LAURIE

"I'm hoping by 2025 we are able to protect and repopulate endangered environments and maybe even revive some extinct species"

JACK

"Alternative energy sources will be more important than ever, so I'm predicting fleets of cars with hydrogen fuel cells on the world's highways"



CHARLIE

"As our understanding of genetics improves, I think we'll see huge breakthroughs in the quest to reverse ageing and prolong human lifespans"

JACKIE

"Elon Musk predicts that manned missions to Mars could happen by 2022. It's optimistic, but there were only eight years between JFK's "We choose to go to the Moon" speech and Armstrong's "one small step" on the Moon"

HOW IT WORKS

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HOW HOW IT WORKS WORKS

Find out how each issue of the mag gets made!

Imagery
Before each article is commissioned we have to consider what photos, illustrations and diagrams to include.

Layout
The structure of a feature can vary depending on the content.

Extras
Timelines, infographics and diagrams help keep information clear and simple.

1 Ideas
The HIW team are constantly on the lookout for new ideas, taking inspiration from the latest news stories and popular media, as well as the curious questions we'd like to know the answers to ourselves!

2 Planning
Once we have lots of article ideas to choose from, the editor organises the issue. The editor and research editor work together to plan out the features and look for appropriate imagery.

3 Commissioning
Article and illustration briefs are then given to the writers and artists to complete respectively. These briefs provide the writers with a template to follow and the illustrators with an idea of what we're looking for visually.

4 Checking
When the writers submit their work it is first checked by the editor, then proofed and, if required, edited by the production editor, then fact-checked by the research editor.

5 Designing
Once the editorial team has seen the articles, they are sent on to the designer and assistant designer to turn the plain text document into the exciting visual version that you see inside the magazine!

6 Proofing
The editorial team re-checks all of the documents before they are sent to the printers. The editor and designer give each page a final check to make sure everything looks ok.

7 Printers
Once we are happy with how the magazine looks, it is sent out to the printers, where the digital documents are turned into the physical copies. Once this stage is complete, it's time to send the magazine out.

8 Distribution
The magazines are sent to subscribers and stores, and digital copies are uploaded to the online stores, ready for the on-sale date. Then it's on to the next issue of **How It Works**!

The finished mag
Each issue is commissioned, written, produced and checked in just four weeks.